THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL.

VOL. 31. Thursday, June 25, 1925. No. 462.

PUBLISHED WEEKLY.

Subscription Terms: 15s. per annum.

Foreign and Colonial, 17s. 6d. per annum.

All Subscriptions are payable in advance.

All communications to be addressed to the Editor, or to the Publisher, as the case may be, of

THE FOUNDRY TRADE JOURNAL,
BESSEMER HOUSE, 5, DUKE STREET, ADELPHI,
LONDON, W.C.2.

Contents.

	PAGE
Foundry Technical Reports and their Utilisation ..	533
Institute of British Foundrymen—Annual Convention	534
Aluminium-Alloy Castings	539
The Mechanical and Physical Properties of Cast Iron—Part I	545
Heat-Resisting Cast Iron	549
Gazette	554
Personal	554
Trade Talk	555
Correspondence	558
Scrap Supplies for the Foundry	559
Cast-iron Houses	559
Foundry Extension at Falkirk	559
Foundry Query	559
Iron and Steel Markets	560

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

Institute of British Foundrymen.

PRESIDENT, 1924-25, R. O. Patterson, Blaydon-on-Tyne.

LIST OF SECRETARIES—

General Secretary: W. G. Hollinworth, 38, Victoria Street, London, S.W.1.

Lancashire: T. Makemson, 21, Beresford Road, Gorse Hill, Stretford, Manchester.

Birmingham: H. James Roe, 33, Herbert Road, Bearwood, Birmingham.

Sheffield: R. Village, Albion Foundry, Whittington Moor, near Chesterfield.

Scottish: J. Bell, 60, St. Enoch Square, Glasgow.

London: H. G. Sommerfield, Charterhouse Chambers, Charterhouse Square, London, E.C.1.

Newcastle-on-Tyne: Colin Gresty, 93, Queen's Road, Monkseaton, Northumberland.

East Midlands: H. Bunting, 17, Marcus Street, Derby.

West Riding of Yorkshire Branch: A. Love, 232, Gladstone Street, Bradford.

Wales and Monmouth Branch: J. J. McClelland, M.I.Mech.E., Druslyn, Bishops Road, Whitechurch, Glam.

Welsh Engineers' and Founders' Association.

Secretary: F. J. Griffiths, 20, Fisher Street, Swansea.

Foundry Trades Equipment & Supplies Association.

Secretary: K. S. Bridges, Avenue Chambers, Southampton Row, London, W.C.1.

Foundry Technical Reports and their Utilisation.

The recent annual conference afforded us an opportunity of discussing with three prominent metallurgists, whose work it is to submit reports to foundries on technical questions, the use made of their reports. Primarily in every case these reports are marked "Private and confidential," which creates in the mind of the recipient an undesirable effect. *The phrase is far too often mistaken for "personal."* These documents are not personal; they belong to the works in general and the technical staff in particular.

A report from such institutions as the British Cast Iron Research Association or the Falkirk Technical Institute is valueless until such time as it is being used by the skilled and unskilled men of the industry. If there is a foundry in Great Britain which is dissatisfied with the nature or type of report received, let them ask themselves what they have done to extract the best therefrom. It would be interesting to learn how many academic reports are filed away in a practical manager's office and how many practical ones stowed away in the corner of a laboratory. Do such people imagine that once—when time allows—they have thoroughly digested what amounts to indigestible reports, they will know as much as the "other fellow"? We can assure them in advance they will not. There is only one sane course to take to deal with a technical report, and that is to submit it to the whole of the technical staff, unless it be too large, in which case it should be truly representative.

If a report be poor or defective in some particular, or of a useless type, then the works technical committee can send to the issuing body a representative reply. If only this could become general the directors of research organisations would be in an infinitely better position to visualise and to control their work so as better to meet industrial needs. As a consequence, the work of an association would be much more truly co-operative.

Meetings of the technical staff, even though it may consist of the owner, a foreman and a charge hand, should be held weekly. If they do not participate in any research organisation, then they should examine carefully current technical literature, or published information relative to jobs in hand or to be started. The factors which have prevented this method being universally utilised are want of vision and lack of enterprise. If a foundry manager pleads that he is too busy, we suggest that his mental make-up lacks organising ability. The institution of technical "board meetings" is equally as important as a directors' meeting. It is as essential to ascertain the technical position and potentialities of an organisation as it is to learn the financial.

INSTITUTE OF BRITISH FOUNDRYMEN.

ANNUAL CONVENTION AND BANQUET AT GLASGOW.

(*Continued from page* 530.)

Election of other Officers.

THE PRESIDENT remarked that he had now a very pleasing duty to perform, and that was to submit the name of Mr. V. C. Faulkner for the post of senior vice-president. His enthusiasm for the industry was well known, and he had literary powers above most of his colleagues in the membership. It did seem to him that Mr. Faulkner would make an excellent President when his time came along for holding that office.

MR. OLIVER STUBBS seconded the nomination of Mr. Faulkner, senior vice-president. Those who had come into contact with the latter gentleman knew he would make a thoroughly good officer because he had the best interests of the industry and the Institute at heart.

The proposition was put to the meeting and carried unanimously.

MR. V. C. FAULKNER, who seconded, said that Mr. Goodwin joined the Institute as far back as 1905. He had had a message from Mr. Goodwin regretting that a sudden call to town had prevented him from taking part in this conference. The Institute could congratulate themselves that Mr. Goodwin had allowed his name to go forward. The proposition was carried unanimously.

MR. H. J. YOUNG proposed and MR. G. E. ROBERTS seconded the re-election of Mr. F. W. Finch as honorary treasurer, the former remarking that Mr. Finch was a founder of the Institute and its first secretary.

Mr. W. G. Hollinworth was re-elected general secretary, sympathetic references being made to his health. A telegram was dispatched conveying the greetings of the Conference. As the result of a ballot, Messrs. W. T. Evans, H. Winterton, T. Harley, A. Firth and J. Haigh were elected to the Council.

OUTSIDE THE CONGRESS HALL.

MR. FAULKNER, in the course of a brief acknowledgment, said he had to thank the members most sincerely for having elected him as senior vice-president. The impression had rather been borne in upon him that morning that the post was no sinecure. Next year the work might be of a more extended nature because London was rather a difficult district in which to organise a conference. Not only so, but they would have next year the International Congress in Detroit City. Personally, he hoped that as many people as possible would accompany him to America in October of that year. An International Committee was being formed, and his colleague (Mr. Delport) was leaving for the United States in the near future so as to bring back the necessary data and information. They were desirous of ensuring that not only Britain but Europe might be adequately represented in this conference.

MR. PATTERSON proposed the election of Mr. J. T. Goodwin, of Sheepbridge, as junior vice-president, remarking that Mr. Goodwin was a very old and valued member of the Institute. He had taken a considerable interest in the formation and conduct of the British Cast Iron Research Association. He was confident that when the time came Mr. Goodwin would make an ideal president.

Messrs. F. J. Cook, T. H. Firth and O. Stubbs, all past-presidents, were re-elected trustees, and Messrs. J. & A. W. Sully & Company the auditors.

Whilst the ballot was being taken MR. CAMERON delivered his presidential address, in which he said:—

PRESIDENTIAL ADDRESS.

Gentlemen,—It is five years since our last Conference was held in Glasgow under the presidency of Mr. Riddell, and it is my privilege to welcome you again to Scotland, where I trust we shall have a successful gathering and be favoured with good weather.

It is a matter of regret that the coal and metal industries are extremely depressed, especially locally. Only the foundries making light castings have their output approaching the normal, while some of the larger shops and foundries have not been so quiet for many years. The industry, however, has weathered many a storm in the past, and

it is to be hoped that the present conditions will speedily disappear. It is during such periods that progressive firms take advantage of the quiet spell to carry out improvements and re-organisation. There is time to overhaul obsolete plant, to improve practice and conditions of work, and to effect economies. It is indeed in such times that the accumulated experience and knowledge of the Institute become most valuable.

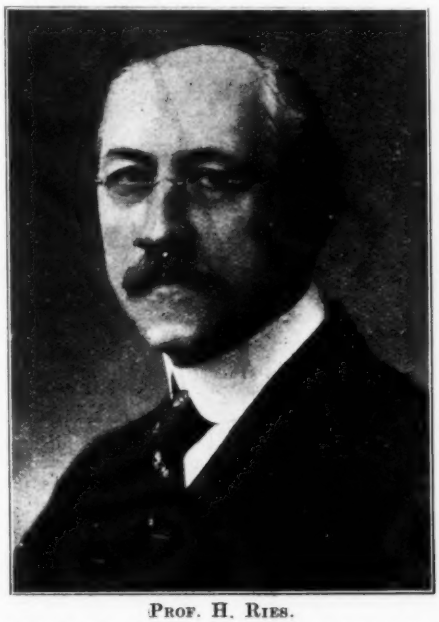
In the course of the year the Institute has been sorely bereaved by the loss of its first president, Mr. Robert Buchanan, and by one who, had his health not broken down, would have been elected your president to-day. In Mr. Broughall I was fortunate enough to make a warm personal friend, and have on more than one occasion enjoyed his hospitality. He was a fine foundryman, equipped better than most of us, and he put the stamp of efficiency on everything he undertook. The places left vacant in our ranks by the loss of those two members will be hard to fill, but their example is bound to be a stimulus to the younger generation of brilliant metallurgists and foundrymen who have in recent years become a promise to our future.

Now that our Institute has completed its twenty-first birthday and passed the adolescent stage, it is an opportunity to go back to the early days and note the steady growth and development and compares its standing and importance to-day with its modest outlook twenty years ago.

When we take into consideration the adverse factors which have operated for some time, the depression, the unemployment and the higher rates of subscription, the progress made cannot be considered otherwise than satisfactory. The actual work accomplished may be gauged to some extent by the reports of Papers published in the Yearly Proceedings and also in the technical Press. There are also many unpublished which are given and discussed at different branches. In Scotland the interest among the members and their large attendances at the regular meetings is most gratifying, whilst the discussions are invariably spirited and interesting. Another prominent and satisfactory feature in the work of the Institute is to be found in the keen interest and excellent attendances at the meetings of the Council, in spite of the long distances many of the delegates have to travel with the cost and loss of time involved. Facts such as these are a sure index of interest and prosperity.

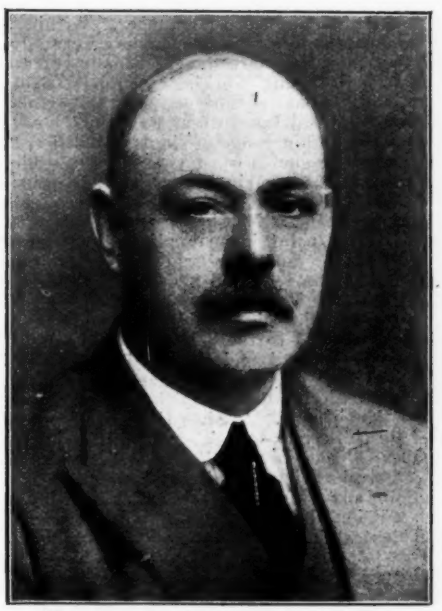
The standard of the Papers given is rising in a very noticeable degree, both in respect of quality and variety as well as scope. Frequently an excellent Paper is read by a keen practical worker, to whom, in some cases at least, the necessary literary work is a real labour. Sometimes when hearing or reading a Paper and discussion something new or original is suggested, and one should take advantage of this by giving it a thorough and patient trial in the foundry.

We are still very conservative and reluctant to leave the beaten track. During the last few years, however, we have seen abroad foundrymen who have not been afraid to strike out on new and original lines in respect of cupola work, gating of moulds, testing and pattern making, and more recently in obtaining cast iron in its strongest physical structure and composition, not occasionally by chance, but regularly and uniformly. Let us trust that our Institute will be encouraged to leave "rule of thumb" and take its share in discovering and making known improved methods and procedure. It should be superfluous to-day to repeat the advice often given that a log be accurately kept daily with full details of cupola



PROF. H. RIES.

Prof. H. Ries, Professor of Geology and head of the Department, Cornell University, has made a special study for a number of years of clays and moulding sands, is the author of a report on moulding sand deposits of Wisconsin, Michigan and Virginia, was one of the pioneer workers in the field work of moulding sand testing; has also published numerous reports on the clay deposits of different States and Canada. He was author of "Economic Geology, and Clays, their Occurrence, Properties, and Uses," and (with Dr. T. L. Watson) "Engineering Geology." Professor Ries is Chairman of the Sub-Committee on Tests of the American Foundrymen's Association, and ex-Chairman of the Sub-Committee on Geological Surveys, also member of the Executive Committee on Moulding Sand Research of the A.F.A., and Engineering Division of the National Research Council. He is an honorary member of the American Foundrymen's Association, member of the American Institute of Mining Engineers, American Ceramic Society, English Ceramic Society, Canadian Mining Institute, and Fellow of the Geological Society of America.



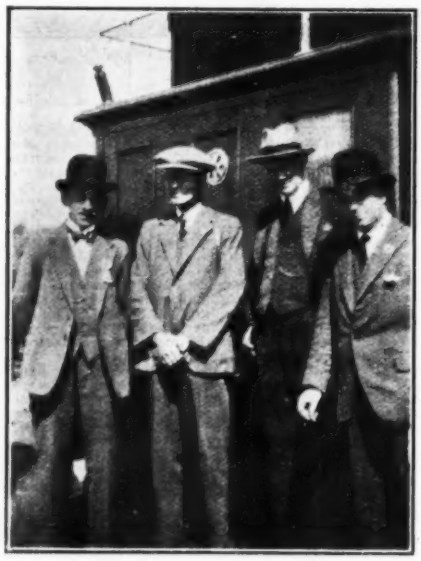
MR. JOHN T. GOODWIN (JUNIOR VICE-PRESIDENT).

Mr. J. T. Goodwin was born on May 3, 1877, at Ripley, Derbyshire. He was a pupil under Mr. Thos. Gillott, general manager of the Butterley Company, Limited, Butterley, Derby. It is interesting to note that the Goodwins held positions as managers in these works since 1780. He afterwards became foreman pattern-maker at the Dearn & Dove Steel Works, Barnsley, and draughtsman to the Holwell Iron Company, Limited, Melton Mowbray, during the erection of the new foundries and engineering shops. He then became engineer for the blast furnaces of the Holwell Iron Company, Limited. Other positions held latterly by Mr. Goodwin include that of works manager to Cochrane & Company, Limited, Middlesbrough; and general manager of the foundries and engineering departments of the Sheepbridge Coal & Iron Company, Chesterfield, which position he has held for the last 18 years. During the war he erected a new factory for the complete manufacture of shells for the Admiralty up to 15-in. diameter, and delivered over 10,000 tons of various shells, bombs, depth charge throwers, etc., and 20,000 tons of castings to Government requirements. He was captain of the Northern Command of the Derbyshire Motor Transport Corps, and in recognition of his services he received the M.B.E. at Buckingham Palace in 1918. He has been a member of the I.B.F. since 1905, and was on the Reception Committee upon their visit to Middlesbrough in 1907. He was actively connected with the Sheffield branch up to the middle of the war, giving several Papers. He is a member of the Council of the B.C.I.R.A., and is a member of the Institution of Mechanical Engineers, the Cleveland Institute, the Institute of Metals, and the Iron and Steel Institute.

charges, output and time-table, and that this be followed up by a daily or frequent test of the metal.

The subject of education has been one of the leading themes for years in presidential addresses. There is no necessity to dwell on the subject. Much is being done in the progressive branches to develop this good work quietly and steadily. It is work in which the Institute takes a deep and real interest and in which it takes the leading part. France has taken up this subject very thoroughly in their specially organised and complete arrangements recently instituted. The main point is to interest the student in his craft, to give him at least some elementary knowledge of the constituents of the metals and raw materials, with instruction as to the proper methods of treating them. The student must be convinced that in his own interests such knowledge is essential, should he have the least spark of ambition and aspire to the position of foreman or manager. Within the last few months two foreign moulders were advertised for a position abroad. Eventually two were selected, both young working moulders, one of whom had taken advantage of the excellent Foundry Technical Institute at Falkirk, the other, who was not within range of similar facilities, had taken a correspondence course on the subject. This was one of the main factors in their securing responsible and remunerative jobs with good prospects of promotion. Membership of our Institute is invariably a point in an applicant's favour for such positions, especially when he has taken advantage of any technical and practical training organised by the branches.

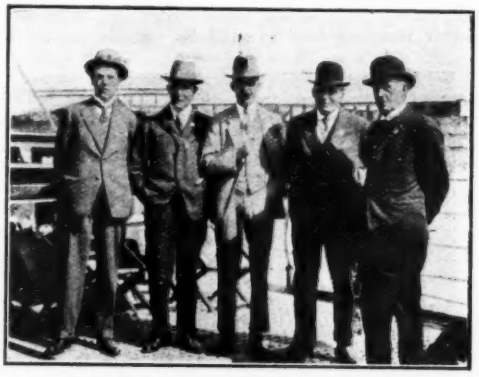
A year ago in his presidential address Mr. Patterson referred to the activities of the British Cast Iron Research Association, and expressed the hope which was entertained regarding its future activities after the difficult initial period through which it had passed. At that time, nearly at the end of its third year of existence, it had obtained a number of members, but its research programme was scarcely in being, and it had not succeeded in raising in any single year the minimum income stipulated by the Government. However, the Council entertained such hope of the future that



A QUARTET OF SECRETARIES.

Messrs. Bell (Scotland), Makemson (Lancs), Sommerfield (London), and Roe (Birmingham).

they undertook with the Government that not only should the minimum income be secured during the succeeding two years, but that the difference between the actual and stipulated income for the first three years should be obtained. The fourth year, closing at the end of this month, has indeed brought a very striking change. Not only has the minimum income been secured, but a considerable fraction of the deficit of the first three years has also been raised, and the future has never been brighter than at the present time. The quarterly Bulletin has been issued regularly; there is a continuously increasing use by members of the Library and Information Bureau. A number of members have been advised on difficulties arising in foundry working, and many have expressed considerable satisfaction with the results, and still more members have been personally visited by the director and consultant. A research programme is in full swing, and investigations are proceeding at the Universities of Sheffield, Manchester and Birmingham, and more recently an important piece of work has been commenced at the National Physical Laboratory. In addition, the Association has acquired its own laboratory and has increased its staff. Important work is also being carried out in the works of various members. The co-operation



PRESIDENTS—PAST, PRESENT AND FUTURE.

Left to Right.—Mr. V. C. Faulkner (Sen. Vice), Mr. R. O. Patterson (Retiring), Mr. J. Cameron (Newly Elected), Mr. F. J. Cook (Past), and Mr. M. Riddell (Past).

between the Institute and the Association has increased considerably, since the Institute's delegate member now acts as a member of the Council of the Association, and the director of the Association has been invited to join the Council of the Institute. The two bodies are also co-operating very closely through the Joint Test-Bar Committee in connection with the establishment of national specifications for cast and malleable iron, the I.B.F. specification being used as a basis for grey iron.

In regard to the future of the industry, there is a vast field for improvement in method, in organisation and in research. The work of the moulder is most interesting. It calls for skill, for resource, for experience gained from the ever changing varieties of work. Too much of his time is taken up in the preparation and handling of sand in ramming and lifting heavy boxes. Modern method is in the direction of eliminating many of these by mechanical means and confining the moulder's work to the exercise of his skill. Great improvements in plant for this purpose have been made, and their adoption by enterprising firms has effected considerable economies in cost of production and on cost. In this respect a plentiful supply of the cheap power about which so much has been heard will be essential, particularly if the advantage of the electric furnace is to become a practical proposition for more general use. There is a growing demand for castings of quality, particularly in regard to cast iron. Engineers require reduction in weight without loss of strength, and the latter improvements in internal combustion engines call for quality which can only be produced by the combination of scientific knowledge hand-in-hand with efficient foundry equipment and procedure. Members of the Institute have taken a leading place in this respect and there is endless scope for further demand and development.

The centre of all foundry work is the cupola, and it is interesting to know that the British Cast Iron Research Association have tackled this important subject, collecting the various details involved, with the view of reaching some approach to reliable standard practice.

Much work has yet to be done in regard to testing, blending and use of sands, particularly in the way of making use of local material. The employment of oil sand cores has received a good deal of attention and is becoming more general, with good results. In this subject alone there is a whole field of useful research.

The problem of transport, especially in foundries engaged in the lighter classes of work, has not, except in exceptional cases, received the consideration which it requires. In a Paper read in Glasgow in February, it was pointed out that in a light castings foundry melting 30 tons per day, the materials handled amounted to approximately 255 tons, 150 tons by the moulders and 105 tons by unskilled labour. These figures, although approximate, are illuminating and show the desirability of making use of modern methods to effect considerable saving in energy, time and unnecessary labour.

So far, I have noted in a very rough sketch a few of the more striking points in the work and progress of the Institute in the past and for the future. It may be on account of the foundryman's art being so intricate and so elusive and consequently so interesting, but in any case it is a very striking fact that our Institute has the faculty of getting the very best out of its office-bearers. The past presidents in particular have given a splendid record of service. They have built up and maintained the present position and have brought to the Institute both honour and dignity. This efficient and constant service has not been confined to presidents, but has been general throughout the branches where the more unobtrusive, but none the less efficient work done by local presidents, committees and secretaries is the most valuable asset any Institute could possess.

Our object at this anniversary period should be to appreciate the spirit of loyalty, enthusiasm and service of those who have gone before and who have so nobly borne the burden of the early struggles. Inspired by their example, let us not be content with the elimination of failures or defects, but let us strive to improve and still improve working conditions and quality until substantial improvement is attained in the melting of metal and in the quality and finish of the castings. To attain this one has to take some trouble, but help is to be found in the interchanges of experience and visits to works which membership implies, and the reward is the realisation of at least part of our ideal, a keener interest in our own work and increased satisfaction and confidence from our customer. I can honestly affirm from my own personal experience that since becoming a member of this Institute I have gained much, primarily in the many friendships made, which to me are even more valuable than the knowledge and experiences which have been considerable.

Gentlemen, I thank you for the honour conferred upon me, and I shall do what I can to maintain the high standard set up by my predecessors in office.

Votes of Thanks for Address.

MR. J. SHAW, Sheffield, said that if Mr. Cameron had provided them with a foretaste of what they had to expect in the coming year, then they were assured of good things. The President had touched on the practical side of the work, and he had given them an incentive to strive to do better in the future. They had been greatly helped by what Mr. Cameron had said to them that day. It afforded him pleasure, therefore, to move that the thanks of the members be extended to the President for his interesting inaugural address.

MR. F. J. COOK, Birmingham, in seconding, remarked that he had a good deal to do with the earlier history of the Association. As the oldest past president of the Institute he could appreciate as much as anyone else the progress that had been made. He well remembered with what fear and trembling the original nine floated the Institute. Two of the original founders were present that day. They had no conception where they might ultimately get to with the Institute. Certainly at first there was a great deal of struggle to push the Association forward, but it was a delight to all of them to note that progress had been made in numbers, while they had also gained in prestige. He felt certain that the good work would continue to be enhanced by the acquisition of the present President.

Retiring President Thanked.

THE PRESIDENT, in calling for a vote of thanks to the retiring President for his services during the past year, remarked that Mr. Patterson had visited all the Branches. He had done what he could to uphold the honour of the Institute, and they were grateful to him for his efforts. Mr. Patterson had undoubtedly put his heart into the work. They knew he would do that, but he had surpassed himself during the year and had put in an extraordinary amount of activity.

MEMBERS AND THEIR GUESTS AT THE BANQUET.

MR. J. SHAW, Sheffield, in seconding, said visits of that kind to Branches in different centres of the kingdom entailed a great deal of time and thought. That was altogether apart from the correspondence that the President had to undertake in replying to points raised by individual members.

MR. R. O. PATTERSON, in acknowledging the vote of thanks, said he was very grateful for their recognition of his work. He could assure them that his year of office had been most interesting. He had visited every Branch of the Institute except one. The experience he had gained had been of invaluable service to him. He had the feeling that the educative advantages of the Institute were not stressed as they ought to be. The meetings for discussion on points of mutual interest and difficulty had gone a long way towards improving the earning capacity of the members. That, at all events, had been his own personal experience, and he had been a member of the Institute since 1905. Nowadays he felt that he must have known very little about foundry work when he joined the Institute.

The remainder of the session was devoted to the reading and discussion of Papers.

Civic Reception.

In the afternoon, and before proceeding to the City Chambers for a civic reception, Mr. Cameron, on behalf of the Institute, placed on the Cenotaph

a laurel wreath, carrying the letters "I.B.F." The members and friends were the guests of the Lord Provost, Magistrates, and Town Council of Glasgow. They were received in the Satinwood Salon by Bailie Angus McDougall, who was accompanied by many of the other magistrates of the city, as well as members and officials of the Corporation.

BAILIE MCDOUGALL, addressing the company in the Banqueting Hall, reminded them that the

MR. F. H. HURREN.

Mr. F. H. Hurren, who read the Paper on "Malleable Cast Iron," was born in London in 1881. He studied chemistry and metallurgy at the Northern Polytechnic under Dr. J. T. Dunn and H. C. L. Bloxam. In 1904 he joined the staff of the Rover Company, Limited, Coventry, to equip and organise a Laboratory in connection with automobile engineering. He was appointed chief chemist and foundry manager in 1910, the foundry having a large output of castings in aluminium, gunmetal, grey iron, and malleable iron. Mr. Hurren has been a member of the Institute of British Foundrymen since 1907, and was president of the Coventry Branch, 1920-21. He is also an Associate of the Institute of Chemistry, 1919, a member of the Society of Chemical Industry, the Institute of Metals, and the Iron and Steel Institute.

Institute was formed 22 years ago. It was inaugurated with the idea of promoting the intellectual welfare of the members. The other side of its origin and inception was to make, if at all possible, for the advancement of the foundry industry. Personally he was glad that he was in a position to congratulate them on the success that had been attained. The demands of modern engineering were now very exacting, and with competition both severe and intensified, it really behoved all foundrymen to take advantage of every opportunity of acquiring knowledge of materials and methods. It did seem to him (Bailie McDougall) that the Institute of British Foundrymen offered a valuable medium for the acquisition of such knowledge.

MR. JOHN CAMERON, the President, appropriately acknowledged the kindness of the Corporation to the members of the Institute. To his mind there was no more suitable place in the whole kingdom than Glasgow for a civic reception to a body such as theirs. Glasgow was strongly tied up with the foundry industry as well as with the huge coal and metal industries. Since that was the acknowledged position, a welcome from its civic rulers was bound always to be very acceptable.

MR. R. O. PATTERSON, the retiring President, and SIR ARCHIBALD MCINNES SHAW joined in the oratory, which, on account of the heat, was brief. In the course of the afternoon the guests were served with light refreshments.

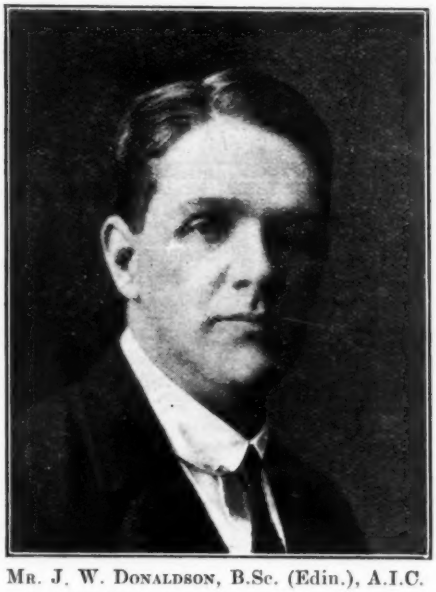
ANNUAL BANQUET.

The annual banquet was held in the Grosvenor Restaurant.

After the usual loyal toasts had been proposed by THE PRESIDENT, and duly honoured, MR. R. O. PATTERSON, retiring President, proposed the toast of "The City of Glasgow," which, in the absence of the Lord Provost, he coupled with the name of Bailie Angus McDougall.

He explained at the outset that the early history of Glasgow commenced in the sixth century. Owing to the exceptionally favourable position of the city geographically, it developed its boundaries very extensively. So much was that the case that whereas the population of Glasgow in 1801 was some 17,000 odd, it was to-day well over a million. It had the mastery of the sea on one side, while it was surrounded by collieries that provided excellent coal. As Englishmen well knew, Glasgow was capable of producing excellent pig-iron. In the earlier stages of its career Glasgow had tremendous difficulties to contend with in order to gain an access to the sea. Indeed, some years ago the River Clyde was only fit for the navigation of small boats. An immense sum of money had, however, been expended in order to bring the sea to Glasgow, and the outlay in that direction had made for the general development and advancement of the city.

BAILIE ANGUS MCDOUGALL, in replying to the toast, said it was often a moot point for discussion whether the Clyde made Glasgow or Glasgow made the Clyde. The greatest problem, however, that faced the city at the moment was the one of extension. No doubt Glasgow was indebted to the Clyde Trust for the foresight and management they had shown. The city had been favoured certainly in having the natural facilities of the Lanarkshire coalfields just at hand to develop their industries, but even making every allowance for all these



MR. J. W. DONALDSON, B.Sc. (Edin.), A.I.C.

Mr. Donaldson, the author of the Paper on "High Temperature Tests of Cast Iron," received his early training in the laboratory of the Carron Company, Falkirk. After a course of study at Edinburgh University and the Royal Technical College, Glasgow, he was on the metallurgical staffs of D. Colville & Sons, Limited, Motherwell, and Wm. Beardmore & Company, Limited, Glasgow, before becoming chief chemist and metallurgist with Scotts' Shipbuilding & Engineering Company, Limited, Greenock, in 1918. He was Carnegie Research Scholar of the Iron and Steel Institute in 1914. In addition to being a member of the Institute of British Foundrymen, Mr. Donaldson is also a member of the Iron and Steel Institute, Institute of Metals, and Society of Chemical Industry. He has contributed Papers to various societies, including a joint Paper with Mr. A. Campion to the Annual Convention of the Institute of British Foundrymen at Birmingham in 1922.

things, he was going to assert that Scottish foresight had contributed to make Glasgow what it was to-day. As a matter of information to their English guests, he would point out that Glasgow had 53 persons to the acre, compared with 33 in Liverpool and Manchester, 21 in Birmingham and 16 in Leeds and Sheffield. They would be ready to recognise after hearing these statistics that the problem of Glasgow in the matter of density of

(*Continued on page* 555.)

Aluminium-Alloy Castings.

By S. L. ARCHBUTT, F.I.C. (National Physical Laboratory).

(*Continued from page* 528).

Age-Hardening.

The mechanism of age-hardening in aluminium alloys has been very clearly and beautifully demonstrated by Hanson and Gayler* in research at the National Physical Laboratory on alloys of aluminium with magnesium and silicon, which show marked age-hardening. In this system the presence of a definite compound between magnesium and silicon Mg_2Si was established. This compound has in polished, unetched sections a

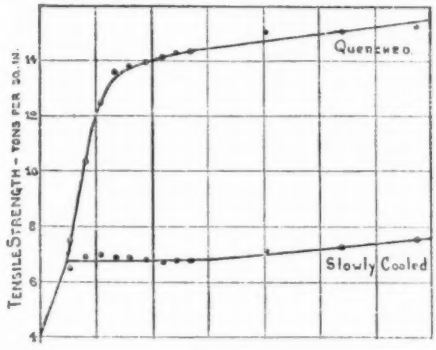


FIG. 6.
(From J. Inst. Met., 1921, 26, p. 344.)

beautiful iridescent blue colour. Characteristic forms of it are shown in the photomicrograph (Fig. 4). It is soluble in solid aluminium, and this solubility was found to decrease with temperature in the manner indicated in Fig. 5.

Slowly cooled alloys did not harden, but quenched alloys did, and the extent of the hardening measured by hardness and tensile tests increased with the amount of the compound in solid solution at the quenching temperature up to the limit of solubility in the solid alloy at that temperature. This is illustrated in Figs. 6 and 7. On slow cooling Mg_2Si separated as free crystals visible under the microscope, but on quenching no separation was visible. The compound was retained in solid solution.

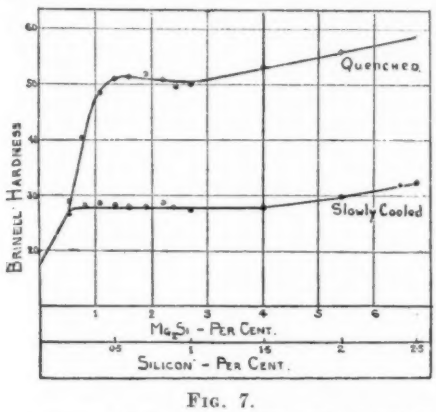


FIG. 7.
(From J. Inst. Met., 1921, 26, p. 344.)

Such a supersaturated solution at normal temperature is not in equilibrium and tends to deposit the excess Mg_2Si. It was thus established that age-hardening was associated with the formation of this super-saturated solution, and there appeared little doubt that it is caused by the tendency of such a solution to revert to a more stable state by the precipitation of excess compound.

* J. Inst. Met. 1921 (2), pp. 321-355.

The generally accepted theory is that a gradual precipitation of fine particles of the compound takes place subsequent to quenching, and that it is the presence of these hard particles within the crystals of the matrix which causes the hardening. Material confirmation of this is shown in photograph Fig. 8 (500 dias.) of the microstructure of a cast specimen of heat-treated and aged "Y"-alloy which has been held at 250 deg. C. for 12 days. Under such treatment the precipitated particles might be expected to grow and become visible under the microscope. The microstructure

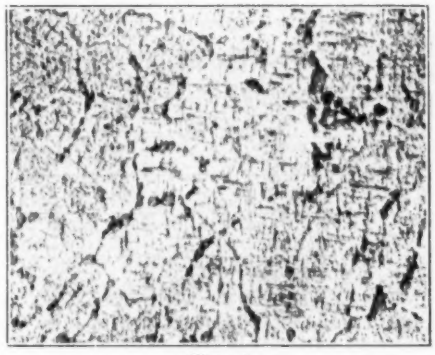


FIG. 8.

indicates large numbers of small needles and rounded particles within the grains.

The explanation of the age-hardening process in certain aluminium alloys thus arrived at leads to the important generalisation that wherever in any alloy a super-saturated solid solution can be formed by quenching, and can subsequently be allowed or caused to revert towards a more stable state by precipitation of minute particles of the dissolved constituent hardening and tempering becomes possible.

Constituents Producing Age-Hardening.

Influence of Composition.—A constituent or constituents may produce age-hardening in an

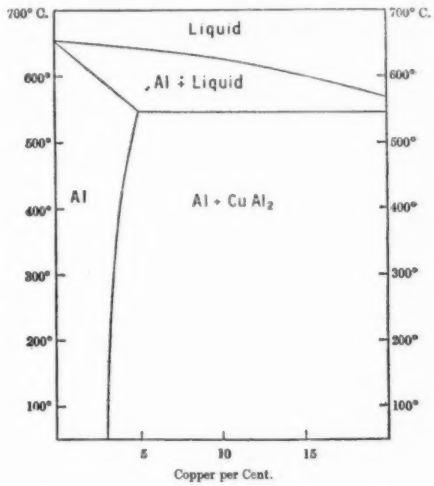


FIG. 9.
(From J. Inst. Met., 1923, 29, p. 509.)

alloy on quenching or rapid cooling, if appreciably soluble in the solid alloy at the quenching temperature and becoming less soluble at lower temperatures. It has been shown that the compound Mg_2Si exhibits such behaviour and produces marked age-hardening.

The compound $CuAl_2$ shows similar behaviour in regard to solubility as illustrated in Fig. 9, where it is seen that the solubility of copper in solid aluminium falls from 5 per cent. at 540 deg. C. to about 3 per cent. at 20 deg. C. Accordingly it might be expected that alloys containing more than 2 to 3 per cent. of copper in solid-solution at, say, 450 deg. would undergo age-hardening on quenching from that temperature. This has been shown to be the case by Hanson and Gayler for both wrought and cast alloys, and will be referred to later. The hardening is illustrated in Fig. 10. Age-hardening has also been demonstrated by the above workers, in the binary zinc-aluminium system, but would appear to be applicable with advantage only to the heavier alloys containing over 20 per cent. zinc.

A consideration of vital importance affecting age-hardening is that the addition to a solid solution of one constituent, of a second constituent also soluble in aluminium, will usually affect the

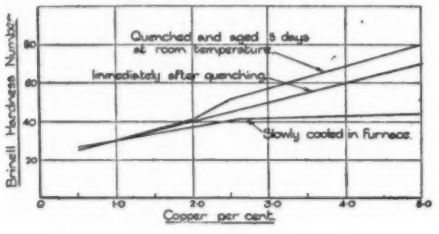

Brinell Hardness Number
Quenched and aged 5 days at room temperature.
Immediately after quenching.
Slowly cooled in furnace.
Copper per cent.

FIG. 10.
(From J. Inst. Met., 1923, 29, p. 495.)

solubility of each. Addition of an insoluble constituent such as iron will have little if any affect. Thus, in presence of magnesium, copper becomes practically insoluble in aluminium at 400 deg. C., whereas normally it is soluble at this temperature to the extent of 3.7 per cent. The solubility of copper in aluminium at 500 deg. C. is reduced from 4.5 per cent. to 2 per cent. by addition of as little as 0.7 per cent. Mg_2Si.

Again, the solubility of Mg_2Si in aluminium at 580 deg. C. is reduced from 1.6 per cent. to 1.1 per cent. by presence of an excess of less than 1 per cent. of magnesium. The effect of this reduction of solubility in diminishing the hardening effect obtainable on quenching is illustrated in Fig. 11.

It is evident, therefore, that to obtain the best possible results from a heat-treatable alloy, careful control of composition is vital, and that in order to exercise this control intelligently accurate

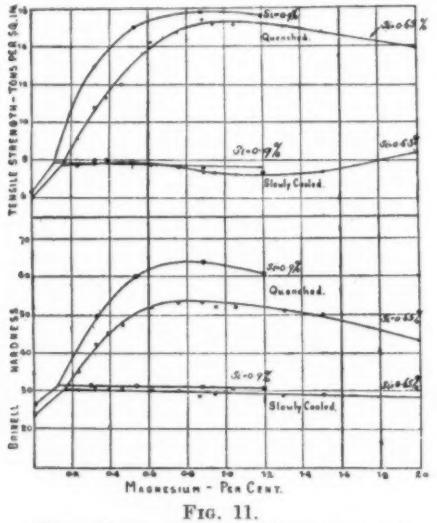


FIG. 11.
(From J. Inst. Met., 1921, 26, p. 344.)

knowledge of the constitution and of the solubility relationship of the constituents in the solid state is essential.

Accelerated Age-hardening.—As already referred to, the process of age-hardening can be hastened by employing temperatures above atmospheric normal. Fig. 12 shows graphs of age-hardening after quenching for an aluminium alloy containing copper 3.74; Mg 1.08; Si 0.30, and Fe 0.52 per cent.

It will be noticed that at 25 deg. C. maximum hardness is reached in about four days, but that at 140 deg. C. an equal degree of hardness is reached in a few hours. The further fact will also be noticed that at 140 deg. hardness continues to increase, approaching a maximum value in about five days, which is approximately 30 per cent. higher than that attained at 25 deg. C. At 200 deg. C. the rate of hardening is still more rapid but is followed by a gradual softening, the alloy eventually becoming softer than when aged at normal temperatures. Increase of hardness above that normally reached at atmospheric temperature may be accompanied by decrease in ductility.

It is evident, therefore, that accelerated age-hardening requires careful control to avoid on the

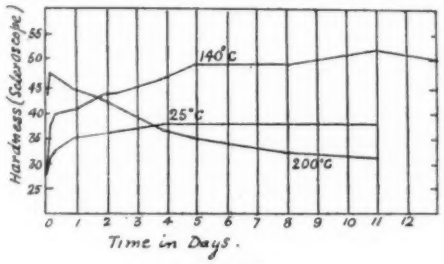


FIG. 12.

one hand attainment of too great hardness at expense of ductility, and on the other hand softening.

Tempering.—In analogous manner to certain quenched steels, age-hardened aluminium alloys can be further hardened by exposure to temperatures above atmospheric; temperatures between 150 to 200 deg. C. are suitable for aluminium alloys. An example of this in the case of binary copper-aluminium alloys has been described by Hanson and Gayler, and is referred to later. Results are illustrated in Fig. 13. Age-hardened alloys containing copper-nickel-magnesium and silicon (*e.g.*, "Y"-alloy) can be similarly further hardened by such treatment.

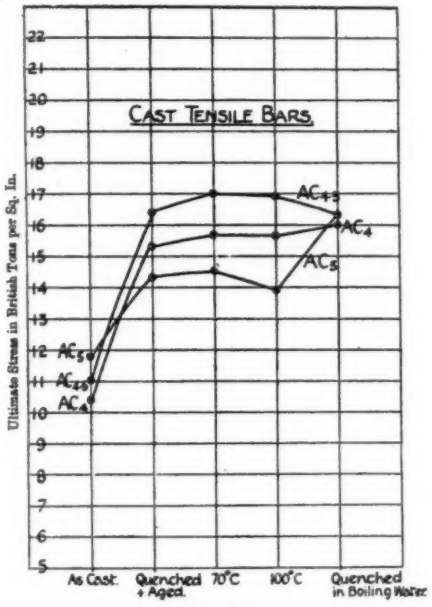


FIG. 13.
(From J. Inst. Met., 1923, 29, p. 498.)

Cast *v.* Wrought Alloys.

Heat-treatment of Cast Alloys.—It has been shown that to produce age-hardening in an alloy, it is necessary firstly to have present a constituent or constituents exhibiting differences in solubility at high and low temperatures, and secondly to bring about maximum solution possible at the

quenching temperature. The larger the individual crystals of these constituents, the more slowly will they diffuse into the solid alloy and the longer the exposure required at the high temperature before quenching. It is this fact, coupled with ignorance of the true mechanism of age-hardening, to which previous lack of success in producing hardening in cast alloys is attributable.

Hot-working breaks up the crystals of the constituents, disseminates them, and at the same time exposes them to temperatures favourable to solution, so that if sufficient hot work is applied, solution is very effectively brought about at the working temperature, and the actual period of heating at the quenching becomes comparatively unimportant.

Circumstances are very different in the case of castings, however, and the period of heating before quenching is of vital importance. Hours instead of minutes are required, depending upon the coarseness of grain and the maximum temperature which can safely be employed.

Duralumin.—Guillet* has recently demonstrated that by suitable treatment duralumin castings, both sand and chill, can be caused to age-harden to an extent comparable to that of the wrought alloy. Examples of his results are given in Table I.

TABLE I.—*Hardness of Duralumin Castings.**

Condition.	Not quenched.		Hardness (Brinell). Immediately after quenching.		96 hrs. after quenching.	
	Sand.	Chill.	Sand.	Chill.	Sand.	Chill.
As cast ..	53	60	—	—	—	—
Annealed ..	45	54	—	—	—	—
½ hr. at 475° ..	—	—	49	59	62	80
1 ,, ..	—	—	57	58	74	84
3 ,, ..	—	—	56	59	73	88
10 ,, ..	—	—	61	69	85	95
10 hrs. at 525°	—	—	—	—	98	104

* Rectangular plates 125 × 100 mm., recessed, thickness varying from 10 mm. to 6 mm.

The effect of grain size, period of soaking before quenching, and temperature are clearly shown.

The hardness reached on ageing is comparable with that of the age-hardened wrought-alloy. The shear strength of the chill-cast plates was increased from 9.8 tons per sq. in. as cast, to 14.2 tons per sq. in.

Copper-Aluminium. — The profound improvement in the properties of cast binary copper-aluminium alloys containing 4 to 5 per cent. of

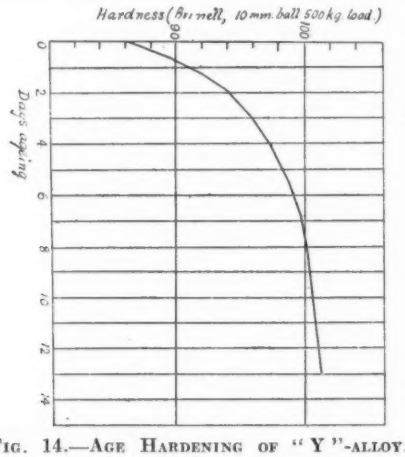


FIG. 14.—AGE HARDENING OF "Y"-ALLOY.

copper, which can be obtained by heat-treatment, has been demonstrated by Hanson and Gayler and is illustrated in Fig. 13. In this instance the bars were chill-cast 1-in. dia. and were heated at 500 deg. C. for 24 hours before quenching. The period of ageing at normal temperature was six days. The further improvement obtained on tempering in certain cases is shown. Accelerated ageing by quenching to 100 deg. C. in boiling water and holding in the boiling water for one hour produced an equally good effect.

It is seen that in the case of the 4.5 per cent. copper alloy, the tensile strength was raised from 11 tons per sq. in. as cast, to about 17 tons, and elongation from 14 per cent. to 18 to 25 per cent. on 2 in.

A tensile strength of 17 tons per sq. in. in a light aluminium alloy casting is remarkable, and has only been exceeded in the case of the alloy "Y" (copper 4, nickel 2, magnesium 1.5 per cent.).

The value of a heat-treated copper-aluminium alloy such as the above will depend on its resistance to deformation under bending fatigue, etc., stresses. It may be that like the tough but ductile silicon alloys, it will prove too plastic.

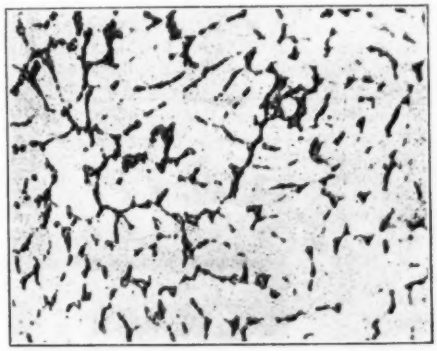


FIG. 15.—"Y"-ALLOY 1-IN. DIA. CHILL × 150 DIAS.

It has a strength/weight ratio (ultimate stress in tons per sq. in. divided by specific gravity in grammes per cc.) of 6.0, second only to heat-treated "Y," the normal value for which under similar conditions is 7.2.

Preparation and Properties of "Y"-Alloy.

The preparation and properties of this alloy were first described in the 11th Alloys Research Report, Institution of Mechanical Engineers, 1921. Further information regarding preparation and heat-treatment has been given in subsequent papers to the Institute of Metals.

A remarkable increase in strength is attainable with this alloy by age-hardening treatment. The tensile strength of 1-in. dia. chill-cast bars is raised from about 14 tons per sq. in. as cast to 20 tons and over, with an appreciable improvement in ductility, heat-treated bars giving 4 to 7 per cent. extension on 2 in.

A typical age-hardening graph for a chill-cast bar quenched from 520 deg. C. is shown in Fig. 14. It will be seen that the alloy requires

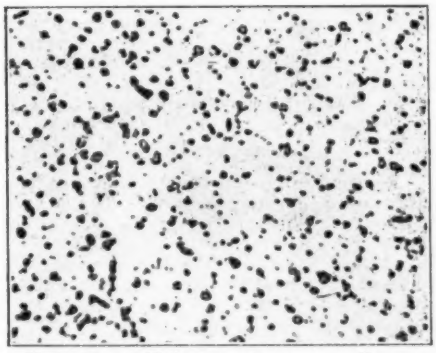


FIG. 16.—"Y"-ALLOY 1-IN. DIA. CHILL, HEAT TREATED × 150 DIAS.

not less than eight days at atmospheric temperature to approach maximum hardness.

The effect of heat-treatment on the microstructure is illustrated in Figs. 15 and 16 at 150 dias.

Age-hardening can be accelerated as in other alloys by employing higher temperatures, and experiments are in hand at the National Physical Laboratory for the purpose of arriving at conditions suitable for application industrially.

* Revue de Métallurgie, Dec. 1924.

The heat-treatment temperature for obtaining maximum strength should approach 520 deg. C. as closely as possible, but not exceed it. One-in. dia. chill-cast bars require a period of not less than six hours at this temperature before quenching. Sand-cast bars require longer, and large castings may need 24 hours or more, depending on the coarseness of grain, to approach maximum strength.

In the heat-treated conditions the elastic properties and fatigue resistance of this alloy in the cast condition are remarkably high, placing it weight for weight in a class by itself in comparison with other available casting alloys.

TABLE II.—*Properties of "Y"-alloy.*

	As cast.	Cast, heat-treated.
Density, grammes per cc. ..	2.79	2.79
Elastic limit, tons per sq. in. ..	5.00	7.00
Maximum stress, tons per sq. in.	14.00	20-21
Elongation, per cent. on 2 inches	2	4-7
Safe fatigue range (12 million reversals), tons per sq. inch ..	—	±7.00
Hardness (Brinell, 10 mm. ball, 500 kg. load)	76	105

Typical properties relating to 1-in. dia. chill-cast bars are given in Table II.

An admirable description and comparative *résumé* of the properties of various aluminium-base and magnesium base alloys from the point of view of their use for pistons and connecting rods is given by Aitchison* in a Paper presented to the Institution of Automobile Engineers in 1924. Summing up advantages and disadvantages of the various cast alloys for use for pistons, he suggests the balance of advantages, excluding "Y"-alloy, lies between an 8 per cent. copper-alloy and a magnesium-base alloy containing 6 per cent. aluminium. In regard to "Y"-alloy he says: "On paper 'Y'-alloy is probably the best alloy of all those proposed for pistons, particularly when used in the heat-treated and aged condition. At the present time, however, there appear to be difficulties in carrying out the heat-treatment satisfactorily on a commercial basis, so that the alloy has to be considered in the as-cast (or cast and annealed) state. Even then it is quite as good as any of the other alloys and rather better than most. If, therefore, the technique of founding is improved, and pistons in 'Y'-alloy can be turned out with the same satisfaction and regularity as in, say, the 8 per cent. copper alloy, it will probably be adopted quite widely."

There is no question that the technique of founding this alloy has now been satisfactorily developed in more than one aluminium foundry of note in this country, and also the heat-treatment of the simpler types of castings, such as pistons. Larger castings, such as the crankcases of high-powered aircraft engines, present greater difficulties, which, however, are in the way of being overcome.

* "Light Alloys for Pistons and Connecting Rods."

Heat Treating Al-Alloy Castings.

In heat-treating castings of any aluminium alloy, particularly large castings, it must be borne in mind that at high temperatures they are readily distorted, and great care must be taken to handle them in a proper manner during removal from the furnace. For large castings, steel jigs must be used to provide support where necessary in the furnace and for handling during quenching. Provision should be made for a possible slight contraction on quenching in the case of "Y"-alloy.

Preparation.

To reach the best results attainable from aluminium alloy castings, particularly when heat-treatment is to be applied, they must be sound and of fine grain, properties not readily obtained in sand castings.

Cast in sand, aluminium alloys are in general inferior in mechanical properties and general soundness to corresponding castings made in metal or chill moulds.

The slower rate of solidification which occurs in a sand mould produces a coarse grain which is in itself detrimental to mechanical properties. These effects are, however, usually accentuated by general unsoundness commonly of the type known as "pinholing" or "speckling."

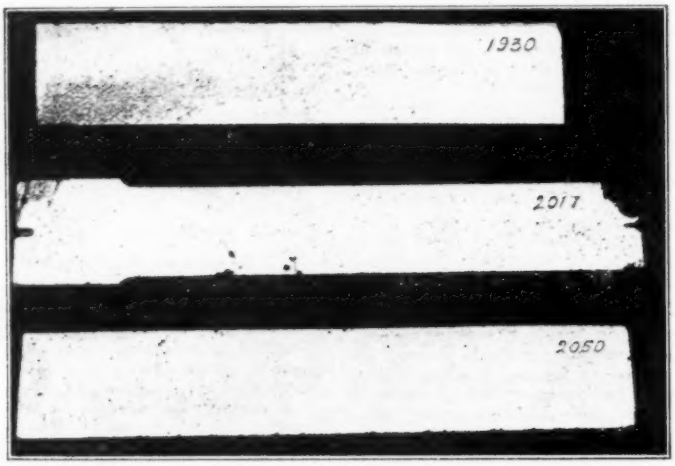


FIG. 17.—LONGITUDINAL AXIAL SECTIONS OF 1-IN. DIA. SAND-CAST BARS, "Y"-ALLOY, MACHINE FINISH, ¾ ACTUAL SIZE.

The "pin-holes" are small cavities fairly uniformly disseminated through the body of the casting; they are revealed on machining as shown in Fig. 17.

Coarseness of grain and pinholing are accentuated in sand castings by high pouring temperates; if melting and pouring temperatures are kept low, considerable improvements can be effected in respect of these defects.

In a recent paper to the Institute of Metals* an account was given of some experiments carried out at the National Physical Laboratory for the purpose of determining the cause of "pinholing" or "speckling" and of improving the properties of aluminium alloy castings generally, particularly sand castings. This work forms part of the programme of research on light alloys in progress at the laboratory for the Aeronautical Research Committee, and is carried out under the auspices of the Engineering Research Board of the Department of Scientific and Industrial Research. Permission was given to publish the results, and it is hoped some account of them will not be unwelcome here.

Under the most carefully controlled conditions, employing normal foundry practice and treatment of melts, it has not been found possible at the laboratory to effect more than a certain degree of improvement in soundness of sand castings.

* Archbutt, "A Method of Improving the Properties of Aluminium Alloys Castings," Institute of Metals, March Meeting, 1925.

In experiments with "Y"-alloy, using a 1-in. dia. bar as a standard form of casting, dry cold sand moulds, melting temperatures not exceeding 730 deg. C., pouring temperature as low as 650 deg. C., and ample risers and runners, the general order of density of cast bars, unmachined, is 2.735 with an occasional value as high as 2.750. These values are to be compared with 2.780 for corresponding bars cast in metal moulds.

Average tensile properties of these two classes of bar in the cast condition are as follows:—

	Sand moulds.	Metal moulds.
Density with skin on	2.735	2.798
Yield stress (tons per sq. in.)	—	11.4
Ultimate stress ,, ,,	10.5	14.8
Elongation per cent. on 2 in.	0.5	2.5

It is well known at the Laboratory and probably in most aluminium foundries that pin-holing can be eliminated in castings of normal thickness by employing metal moulds.

It is the case, for example, with 1-in. dia. bars of "Y"-alloy and other aluminium alloys.

The fact has also been observed at the Laboratory that very slow solidification such as occurs when a melt is allowed to solidify in the pot in the furnace also inhibits pin-holing. In the case of a sand-cast piston in 3L11 alloy sent to the Laboratory for examination, which exhibited profuse pinholing on machined surfaces, a portion was remelted and caused to solidify slowly in a small crucible. A polished section of this ingot was practically free from pin-holing and gave a density of 2.812 compared with 2.769 for material from the piston.

It became evident, therefore, that both rapid and very slow solidification inhibited pin-holing, and that some intermediate rate such as occurs in a sand mould is most favourable for its formation. These facts, together with others, led to the conviction that the cause of pin-holing is occluded gas, and particularly that portion of gas which is liberated during the act of solidification.

If solidification is sufficiently rapid as in a metal mould, it would appear that the occluded gases in the melt are not liberated but retained in solution in the solidified alloy. If solidification is sufficiently slow the gas is liberated and enabled to free itself from the solidifying melt, while at intermediate gates it is liberated from solution but entrapped in the form of minute bubbles, causing pin-holing. It seemed probable, therefore, that if a melt were slowly solidified it would largely rid itself of occluded gas, and that castings poured from the remelt would exhibit improved soundness.

Experiments on these lines were immediately successful. The treatment consisted in allowing a melt to solidify slowly in the uncovered crucible (Morgan Salamander) in the furnace. As soon as it was solid, and without further cooling, the crucible was covered, the furnace re-lighted, and the metal re-melted, raised to the required temperature and castings poured. From melts of 10 to 20 lbs. of "Y"-alloy, treated in this way, 1-in. dia. bars cast in sand were obtained, giving without any machining a density of 2.78 and higher.

An almost entire absence of pin-holing was observed on light machining, the surface appearance closely resembling that of a chill-cast bar. Very uniform ultimate stress values were obtained from bars from these melts varying from 11.3 to 11.8 tons per sq. in. (as cast), representing an increase in strength of the order of 10 per cent. over that of sand-cast bars from untreated melts.

The improved soundness obtained by the treatment above described is illustrated by bar sections 2030 and 2046 in Fig. 18.

During the above treatment small explosions occasionally occurred at the surface of the melt, suggesting that inflammable gas was being ejected and igniting.

Preliminary ingotting of aluminium alloy melts may therefore be decidedly advantageous, provided the rate of solidification of the ingots is sufficiently slow, but marked improvement is not to be expected from ordinary ingotting in metal moulds.

Further experiments were made with "Y"-alloy in which treatment of melts on the lines indicated above were modified as follows: (1) The slowly solidified and remelted alloy was ingotted in chill and then remelted. A 12-lb. melt was treated in this way, and four 1-in. dia. bars cast in sand. Two of these were tested and gave the following excellent average results: Density machined, 2.774; ultimate stress (tons/sq. in.), 12.20; and elongation per cent. on 2 in., 1.0; (2) slow solidification and remelting was repeated three times on a melt before pouring castings. Unsatisfactory results were obtained from a 10-lb. melt treated in this way; and (3) slow solidification was applied to hardener alloys only. Some excellent results were obtained from melts treated in this manner.

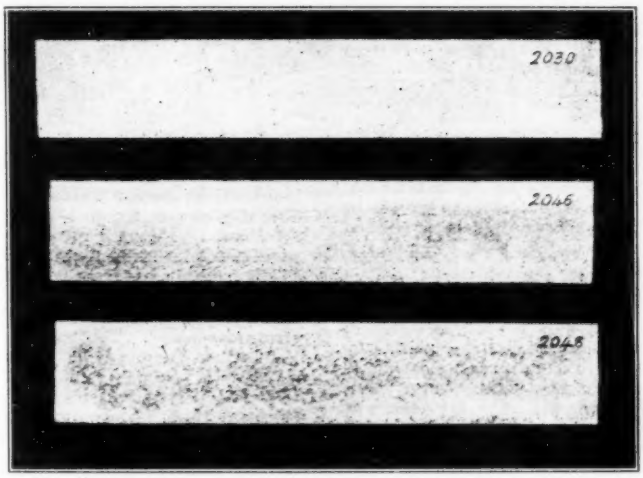


FIG. 18.—LONGITUDINAL AXIAL SECTIONS OF 1-IN. DIA. SAND-CAST BARS. "Y"-ALLOY, MACHINE FINISH. TREATED METALS ⅔ ACTUAL SIZE.

In the majority of the experiments described above, stirring or other disturbance of the melt liable to introduce gas was purposely avoided after remelting subsequent to slow solidification.

Analytical results on small ingots poured before and after the pouring of test bars, indicated some tendency towards concentration of added elements in the lower layers of the remelted alloy. In anticipation of this, a 10-lb. melt was slowly solidified, remelted, and the remelt stirred in a normal manner before pouring. The density, tensile strength, and appearance of machined surfaces of bars from this melt were up to the general standard reached with unstirred melts.

It would appear, therefore, that careful stirring after slow solidification may be employed without detrimental effects.

In all the melts referred to above, notched-bar aluminium of high purity was employed, giving the following analytical results:—

Aluminium "T" per Cent.—Iron, 0.16; silicon, 0.16; copper, trace; and aluminium (diff.), 99.68 per cent.

This metal was tough and ductile under the hammer, and the bars required many reversed bending blows to fracture them at the notches.

In the course of the experiments with this metal, a consignment of aluminium, also in the form of notched bar, was received at the Laboratory. This metal was labelled "Made in Norway," and gave the following results on analysis:—

Aluminium "U" per Cent.—Iron, 0.21; silicon, 0.29; copper, trace; and aluminium (diff.), 99.50 per cent. Aluminium "U" is seen to be of high purity but not equal to aluminium "T" above mentioned.

This metal behaved very differently from the "T" metal under the hammer, breaking quite short in a brittle manner.

Employment of aluminium "U" immediately upset the regular and consistent character of results, as will be seen from Table III:—

TABLE III.—*"Y"-alloy Melts with "U" Aluminium.*

Melt No.	Weight, lbs.	Conditions.	Average density of bars.	Appearance on machining.
YV2015	12	Slowly solidified and remelted.	2.741	Marked unsoundness and pinholing.
YV2018	20	do.	2.729	Serious unsoundness and pinholing.
YV2017	20	Copper hardener only slowly solidified.	2.718	do.
YV2024	12	Ordinarily melted	2.752	Marked pinholing.
YV2030	20	Ingot and scrap from YV2017 remelted and slowly solidified.	2.775*	Slight pinholing.

* A longitudinal section through the axis of one of these bars, finished with a fine milling cut, appeared perfectly sound and free from pinholing as illustrated by bar section 2030 in Fig. 18.

It will be seen that on a first application of the slow solidification treatment, very inferior results were obtained from two melts of 12 and 20 lbs. respectively; also from a 20-lb. melt, YV2017, in which the copper hardener only had been treated before use, a method which, when using "T" aluminium, had given good results.

On applying the slow solidification treatment to a remelt of YV2017, excellent density and soundness were obtained from bars poured at 650 deg. It would appear from these results that with certain grades of metal more than one application of the treatment in question may be necessary.

The aluminium in this particular instance was suspected of containing an unusual amount of occluded gas. To obtain evidence in the matter some melts of this metal alone were made and 1-in. dia. bars cast in sand, under conditions similar to those employed with the melts already described. The density of the bars unmachined was determined, and they were then lightly machined and examined for appearance.

Particulars and results of these melts are given in Table IV:—

TABLE IV.—*Experiments on Treatment of "U" Aluminium (1-in. dia. Sand-cast Bars).*

Mark.	Treatment.	Density unmachined.	Appearance after machining.
Made in Norway	Section from notched bar.	2.701 2.694	—
V2020 (1) (2)	Ordinary melting	2.639 2.641	General unsoundness causing poor machine finish.
V2021 (1) (2)	Slow solidification treatment.	2.694 2.695	Greatly improved soundness and machine finish.
V2022 (1) (2)	Treatment repeated on ingots and runners, etc., from V2021.	2.673 2.676	Somewhat inferior to V2021.
V2023 (1) (2)	Do. on ingots and runners from V2022.	2.671 2.667	Markedly inferior to V2021.

The results show that (1) ordinarily melted and cast, this particular aluminium gives sand-cast bars of abnormally low density; (2) on remelting and applying slow solidification treatment, normal density is obtained accompanied by great improvement in the appearance of machined surfaces; (3) repeating the slow solidification treatment appears to be detrimental; and (4) the density of the notched bar as supplied is normal, and illustrates the fact previously pointed out that by rapid solidification occluded gas is retained in solid solution, and has little if any effect on density.

In discussion and consideration of the above results, it was suggested to the author by Dr. Rosenhain that removal of small bubbles of gas liberated and entangled in molten metal or alloy might be facilitated by passing through the melt an inert gas such as nitrogen. The following experiment was therefore made.

Employing "U" aluminium, a melt of 12 lbs. of "Y"-alloy was prepared at about 730 deg. C. The crucible lid was removed and the melt allowed to cool in the furnace. Commencing at 710 deg. C., a stream of nitrogen of ordinary commercial purity from a high-pressure cylinder was passed through the melt by means of an iron tube, coated with a wash of alundum extending to the bottom of the crucible. The passage of nitrogen was sufficiently rapid to produce the effect of moderate ebullition of the melt without ejection of liquid from the crucible. From the commencement of passage of the nitrogen, a gas which took fire and burnt with a blue flame was observed to be escaping from the surface of the melt together with the nitrogen. The melt took approximately 20 minutes to cool from 710 to 650 deg. C., and it was during the first ten minutes or so of this cooling that the inflammable gas was evolved in sufficient quantity to take fire.

The melt was held at 650 deg. C. for 15 minutes and then allowed to solidify and cool to 500 deg. C.; nitrogen was passed continuously until the melt appeared solid.

The crucible was now covered, the contents remelted, and two 1-in. dia. bars poured at 650 deg. C. in sand. These two bars, unmachined, gave the following density values:—

Melt No.	Density
YV 2048 (1)	2.795
YV 2048 (2)	2.794

On machining, these bars were found to be remarkably sound and free from pinholing. A longitudinal section through the axis of test bar 2048 (2) above, finished with a fine milling cut, is shown in Fig. 18 and illustrates the excellent soundness of these bars.

The densities recorded indicate a further marked improvement in soundness over and above the best previously obtained by slow solidification treatment alone. The values are almost equal to the best so far obtained from bars cast in metal moulds.

The experiments described and the results obtained from them indicate the possibilities of a method of treating aluminium and certain of its alloys, which eliminates, at all events, a considerable proportion of dissolved gas and thus reduces unsoundness and to a considerable extent removes pin-holing. The process suggested consists in allowing the molten alloy or metal to cool slowly in the crucible in the furnace until it has just completely solidified; without further cooling it is then remelted—it may then be carefully stirred—raised to the pouring temperature and cast. Ordinary ingotting of aluminium or its alloys is not satisfactory, as the ingots cool too quickly and during remelting are too much exposed to the furnace gases.

Passage of an inert gas through the melt during slow cooling previous to solidification has been found to improve still further the soundness of resulting sand-cast bars.

Slightly anomalous results have been obtained in some cases, and it is not yet clear how far the method is of value in other aluminium alloys. Much further investigation is required. The author learnt, and was authorised to refer to the fact in his Paper, that simultaneously and independently Professor C. A. Edwards and Mr. Prytherk, of Swansea, working on the effect of gases in copper (for the B.N.F.M.R.A.), had discovered a similar effect obtained by solidification in the crucible, in the case of pure copper.

It is evident, therefore, that the facts discovered and the method described may have wider application than in the sphere of cast aluminium alloys alone.

In conclusion, it may well be pointed out that aluminium alloys to-day have received a degree of accurate study and scientific investigation which may well claim to be unequalled in any other branch of the study of materials of construction. They therefore come into the hands of the engineer with credentials of a very high order.

The Mechanical and Physical Properties of Cast Iron. – Part I.

By J. E. Hurst.

The primary duty of the foundryman is the production of sound castings of perfect appearance and free from internal defects. After this the foundryman is concerned with the production of castings possessing the highest and best mechanical and physical properties for the particular class of casting with which he is dealing and commensurate with the economic value of the particular casting. A review of the modern position and views regarding these properties of cast iron will therefore be of value to foundrymen, in addition to being of general interest in correlating and presenting under one heading the more recent work carried out in modern investigations.

Nothing serves to show the improvement in modern foundry practice more than a comparison between present-day specifications for cast iron, such as the British Engineering Standards Specification for piston rings, which demands that cast iron shall sustain a minimum tensile breaking load of 16 tons per sq. in., with the earlier specifications demanding a minimum tensile strength of 9 tons per sq. in.

Ultimate Breaking Strength.

The principal tests applied to engineering materials are the ultimate breaking-strength determinations, which are determined by subjecting specimens to stresses applied in different manners until fracture occurs. These tests are still the most widely used and commonly understood tests as applied to cast iron, and the ultimate breaking strength is usually determined either by the application of direct tensile or compressive stresses or by subjecting bars to bending stresses in the form of beams of standard dimensions.

Cast iron is different from most other engineering materials in its manner of failure under breaking stresses. No matter what method is used of inducing fracture in grey cast iron, it is never accompanied by any appreciable plastic deformation, as in the case of other alloys, and the fracture is invariably intergranular unaccompanied by any plastic deformation of the individual grains. The reason for this is readily understood from the structural characteristics of cast iron. Ferrite and pearlite, constituents which are common to both steel and cast iron, are what might be described as plastic constituents, and fail under load conditions by a process of sliding of the internal structure or cleavage planes of the individual grains. This mode of failure is described as plastic deformation, and in actual test-bars of steel makes its appearance by a visible change in shape and dimensions of the test bar in the region of the fracture.

In cast iron these same plastic constituents exist surrounded by large quantities of graphite, a weak non-metallic constituent almost without strength and rigidity, and phosphide eutectic and possibly traces of other eutectics, all of which are hard and extremely brittle. As a consequence, when subjected to stresses, these weak and brittle constituents fail under fairly moderate stress values, below those values which cause any appreciable plastic deformation in the principal constituents, ferrite and pearlite. Consequently the structure as a whole collapses at a stress value coincident with that of the failure of these intergranular constituents.

These considerations at once lead to the conclusion that the strength properties of cast iron are fundamentally dependent on the amount, size and mode of distribution of these constituents, which might be described as the non-deformable constituents, and, broadly speaking, it is a fact that the gradual reduction of the amount and size of these constituents, providing the ferrite and pearlite constituents are not changed in the process, is accompanied by improvements in the mechanical properties with a gradually increasing tendency to fail in a plastic manner. The culminating example of this general rule is to be found in malleable castings.

These fundamental considerations show up immediately in the comparison of the elastic behaviour of cast iron with that of other materials. Stress-strain curves, in which the elongation is plotted against the load, are rarely if ever straight contrary to truly elastic and ductile materials in which the portion of the stress-strain curves which lies within the elastic range is a straight line, indicating simple proportionality between the stress and the strain. We also find that cast iron breaks with extremely little elongation and contraction of area. A typical stress-strain curve for cast iron is illustrated in Fig. 1, and for comparison purposes a stress-strain curve for a steel of similar combined carbon contents has been included in the figure. In steel it will be seen that up to the elastic limit the strain produced is directly proportional to the stress producing it, and this ratio is constant in magnitude up to the elastic limit. In cast iron no part of the curve is straight, and the strain increases in magnitude with increasing stress resulting in the constant variation of the stress-strain ratio. The only

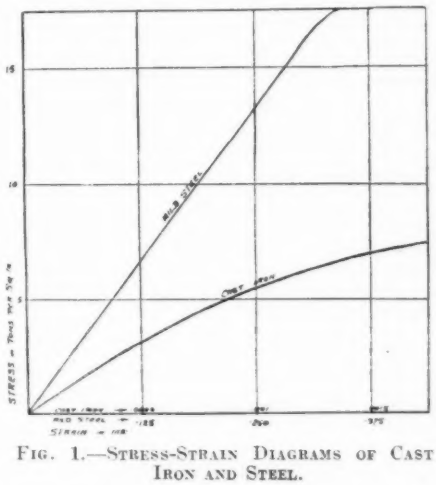


FIG. 1.—STRESS-STRAIN DIAGRAMS OF CAST IRON AND STEEL.

difference between these two materials is the presence of free carbon and phosphide eutectic constituents in the cast iron, and they serve to show the important influence exerted by these constituents.

The stress-strain ratio when determined under pure tensile stress is known as the stretch modulus of elasticity. This ratio *i.e.*, the modulus of elasticity in cast iron, is not a constant quantity, but varies with increasing load.

In a like manner the permanent deformation or the permanent set in cast iron varies with increasing load. Permanent deformation which occurs in plastic materials such as steel after the elastic-limit stress has been exceeded occurs in cast iron with very low values of stress and slight permanent set is always recorded in cast iron when even lightly stressed. No well-defined elastic limit is shown in cast iron, and in those stress-strain curves which show slight indications of proportionality, the elastic-limit indications generally occur at stress values of about one-third the breaking strength.

It is of considerable interest to note that the permanent set resulting from the subjection of cast iron to stress after having been previously stressed is much less than that on a specimen not having been previously strained. This is illustrated by the diagrams in Fig. 2, which show the load extension curves for cast-iron test bars ⅜-in. dia. and 10-in. long, with the permanent exten-

sions resulting from the first loading. If the permanent extensions occurring during each loading are subtracted from the extensions the elastic extension is practically the same in every case. This is attributed to the overcoming of initial strains remaining in the casting after cooling from the liquid state and is removed by annealing the bars at comparatively low temperatures. This effect of annealing is extremely important in such articles as piston rings and cylinders in which permanent set is an important consideration.

Compression.

It is well known that cast iron is considerably stronger when tested in compression than in tension. This fact is again principally due to the presence of the non-deformable constituents. Cast iron which fractures at an ultimate tensile stress of 10 tons per sq. in. may be expected to fail at an ultimate stress of four to five times this value when under compressive stress.

As in the case of the tensile test, the stress-strain curve shows no well-defined elastic limit, and the strain varies with increasing load, resulting in a variable modulus of elasticity value with the magnitude of the stress.

Transverse Bending.

The practice of testing cast iron by determining the ultimate breaking load and the deflection at the point of fracture of standard cast-iron beams originated in the very early days of ironfounding, when cast iron was the prevalent material of construction for beams, girders and columns, and even rails. This test is still extensively used for cast iron. Its absolute simplicity and the reliability of its indications has much to recommend it as a measure of the comparative strength values.

Whilst it is impossible in an article of this nature to deal exhaustively with the theory of bending of beams, it is important to foundrymen to consider some of the essential points of this theory. For more detail, reference should be made to the standard treatises on the Strengths of Materials.*

Cast-iron transverse test bars are beams usually of rectangular section in this country, although cylindrical bars as used in Continental and American works are being more favourably considered. The breaking load and deflection at the point of

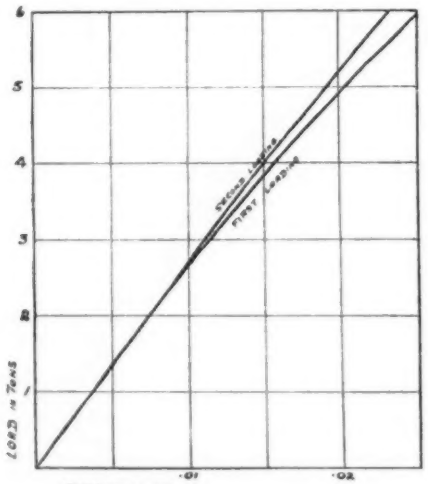


FIG. 2.—PERMANENT SET IN CAST IRON (MORLEY).

breaking on these beams are determined on a system of loading in the manner indicated in Fig. 3.

The tendency of such a beam to shear or deflect under a system of loading is opposed by the resistance of the material to shearing or to tension or compression. It is customary to imagine such beams as built up of a number of fibres or parallel laminæ distributed about a central plane or axis known as the neutral axis. It is assumed that each individual fibre is free to expand or contract longitudinally and laterally under stress as if separate from the other layers. It is also assumed that plane sections cut transversely through the beam normal to the axis remain plane and normal during bending.

In considering the bending of a beam built up of such imaginary layers that at the breaking point the total bending moment (that is, the product of the magnitude of the bending force into the distance from the point about which it acts) applied just exceeds the moment of resistance of all the component layers of the beam. It will also be evident that the stresses induced in the component fibres of the beam will be either tensile or compressive, according to the distance from the point of application of the load, and that there will exist an imaginary layer, in the case of a rectangular beam of truly elastic material, passing through the geometrical centre dividing the fibres into those which are subjected to tensile and compressive stresses respectively. This central fibre is known as the neutral axis.

Under the action of any transverse bending load the intensity of the tensile and compressive stresses induced in the fibres will vary according to their proximity to the point of application of the load and their distance from the neutral axis. The stress intensities will be at a maximum in the extreme fibres at the top and bottom of the section, and will have zero value at the neutral axis. The intensity of stress per unit area in any fibre will be proportional to this distance of the fibre from the neutral axis. In a fibre of sectional area (a) and at a distance (y) from the neutral axis the total stress will be proportional to the

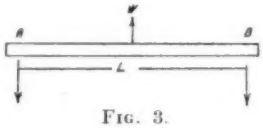


FIG. 3.

quantity (ay) and its moment, or the product of this force into the distance from the point about which it acts is (ay) × (y) = ay^2. The sum of all these moments ay^2 for the imaginary layers of any section is known as the moment of inertia or the moment of resistance designated by the symbol I.

$$I = \Sigma (ay^2) \qquad (1)$$

The stress f in the material at any distance y from the neutral axis, the bending moment M and the moment of inertia I, are connected by the following relation:—

$$\frac{M}{I} = \frac{f}{y} \qquad (2)$$

or

$$M = \frac{I}{y} \times f \qquad (3)$$

The quantity $\frac{I}{y}$ is often called the strength modulus, and, as such, is usually denoted by the symbol Z.

$$M = fZ \qquad (4)$$

The bending moment M for the conditions of a beam simply loaded in the manner indicated in Fig. 3 is obtained by the relation $\frac{WL}{4}$, in which W is the applied load and L the length of the beam between the supports. In a simple rectangular beam of this type $I = \Sigma (ay^2) = \frac{1}{12} bd^3$ and $y = \frac{d}{2}$; therefore $Z = \frac{\frac{1}{12} bd^3}{\frac{d}{2}} = \frac{bd^2}{6}$. Substituting these relations in (4), we have

$$\frac{WL}{4} = f \times \frac{bd^2}{6} \qquad (5)$$

$$W = \frac{4 \times f \times \frac{bd^2}{6}}{L}$$

$$= \frac{2 \times f \times bd^2}{3L}$$

Where f is considered to be the intensity of the breaking stress this formula at once supplies the necessary means for comparing the breaking loads transversely applied to simple rectangular beams

* Morley, Andrews or Unwin.

of different dimensions. From similar considerations the formula

$$W = \frac{0.39 \times f \times D^3}{L} \qquad (8)$$

can be derived connecting the relation between transverse breaking loads on circular bars of diameter D. It can also be shown that the maximum strain or deflection under transverse breaking load can be obtained for beams of rectangular section loaded as in Fig. 4 by the formula.

$$D = \frac{WL^3}{48.E.I.} \qquad (9)$$

Where W = breaking load.
L = length between supports.
E = elastic modulus.
I = moment of inertia.

Substituting the value of I for bars of rectangular section we have

$$D = \frac{WL^3}{48 \times E \times \frac{bd^3}{12}} \qquad (10)$$

$$D = \frac{W \times L^3}{4 \times E \times b \times d^3} \qquad (11)$$

These formulæ are only correct on the assumption that the neutral axis passes through the centre of the area of the section and that the elastic modulus value is constant for varying load conditions. From what has already been indicated it will be appreciated that in cast iron with such a wide difference between the ultimate strength in

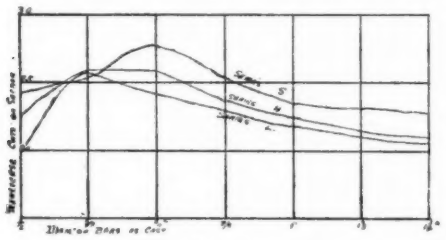


FIG. 4.

tension and in compression that this connot be the case, and the variation in elastic modulus with varying load conditions has already been made clear. For these reasons the above formulæ can only be applied for the conversion of results due to small changes in section where any change in position of the neutral axis is almost negligible. For similar reasons it will be seen at once that the use of this formula is open to the same objection when used for the conversion of transverse into direct tensile as below, and can only be used as an approximation.

$$f = \frac{3\ WL}{2\ b\ d^2} \qquad (12)$$

The inaccuracy of the application of these formulæ for large changes in dimensions has been recently shown by Adamson and Bell* by direct experiment.

Various modifications have been proposed in the above formula to bring them more nearly into line with the observed behaviour of cast iron under stress. The inconstancy of even the observed behaviour of cast iron is such that even most of the modifications proposed do not give a sufficiently closer degree of approximation to the truth as to warrant their use. Undoubtedly the best method to adopt to ensure uniformity and to enable test results to be successfully compared is to adopt some standard form of cast iron bar carefully prepared under standard conditions.

These considerations show at once that the common practice of foundries in using unmachined test bars for the transverse test cannot possibly be expected to be accompanied by any degree of regularity of results, and may often lead to considerable confusion in the interpretation of the results. It is important that bars machined to a dead size should be used for this test, and on these grounds the round bar so frequently recommended is more satisfactory from a commercial point of view in that it is considerably easier to machine.

Frémont has designed a machine for the transverse testing of small machined specimens of cast iron. In this machine Frémont uses small rectangular bars 35 mm. long by 10 mm. wide by 8 mm. thick. Capt. Phillpotts,* in his investigations on steel, subjected notched bars of the Izod impact type either 10 mms. sq. or round bars 0.45 in. dia. to transverse bending in a similar fashion by adapting the ordinary Brinell hardness testing machine of the Aktiebolaget type. This same method could quite easily be adapted to cast iron by most of those foundries possessing Brinell machines. In the Frémont machine an autographic recorder is adapted which records the stress strain diagram under transverse loading conditions. The stress strain diagrams are similar to those illustrated in Fig. 1, and their significance will be more fully discussed under the heading of impact tests.

Unless carried out under extremely well defined conditions and with meticulous care, the tensile test is liable to give extremely erratic results, principally due to the difficulty of ensuring a truly axial pull on the test piece. Any "out of alignment" at once subjects the specimen to bending stresses, the effect of which seriously vitiate the results. As a result of continued experience it is generally acknowledged that unless the tensile test is carried out with extreme care its indications are most unsatisfactory. It is probable that much of the difficulty encountered in correlating tensile and transverse determinations on similar specimens is due to these inaccuracies in the testing operation. On these grounds it is becoming more generally recognised that for commercial testing the transverse test is the more suitable.

Influence of Casting Conditions and Composition on the Ultimate Breaking Strength of Cast Iron.

The early investigations on the conditions governing the ultimate strength properties of cast-iron were conducted principally with the object of determining the influence of the various constituents present on these properties. The early, now classical, experiments of Prof. Turner on the influence of the chemical composition, chiefly the silicon, are now familiar to every foundryman. These experiments showed that with increasing silicon content the maximum ultimate strength properties occurred at different percentages as follows:—

Maximum crushing strength about 0.80 per cent. Si.

Maximum tensile strength about 1.80 per cent.

Maximum transverse strength about 1.40 per cent.

Maximum modulus of elasticity about 1.00 per cent.

An examination of the chemical analyses of the series of samples used in this investigation, as would be anticipated from our knowledge of the constitution of cast iron, shows at once that these variations are not solely due to the silicon content, but are accompanied by a variation in the ratio of the combined and free graphite present. Herein lies the whole difficulty of determining the strictly intrinsic influence of any one constituent on the ultimate strength properties, and it will be appreciated that any comparison of such intrinsic influence must be made at least under conditions of equality in so far as the amount, size and distribution of the combined and free carbon constituents are concerned. This is not an easy matter, and a lot of confusion of thought arises from this circumstance.

From what has been said earlier in this article the condition of the carbon and all those features both relating to the composition and casting, which influence the condition of the carbon may be expected to have a vital influence on the ultimate strength values. It is therefore necessary to define what is meant by the intrinsic influence of any constituent. By this is understood the influence of increasing percentages of the particular constituent regardless of its influence on the carbon content, and under the conditions of cooling and casting exactly identical in all cases. We have practically no information on this intrinsic influence. In the case of silicon Dr. Hatfield† has been able to show that the presence of silicon in amounts usually met with in commercial irons and

* J.I.S.I., 1924, Vol. 1.

* Institute of Automobile Engineers, 1918.
† J.I.S.I., 1906.

under identical conditions of carbon content, has no influence on the ultimate strength values. Manganese and sulphur are probably similar, and their intrinsic influence is very small. The intrinsic influence of phosphorus is probably a tendency to lower the ultimate strength values, although it must be admitted that this yet remains to be clearly demonstrated.

It is a very fair assumption that the intrinsic influence of the elements usually present in cast iron is identical to their influence in normal mild steel or iron, in which alloys the factor of the influence on the condition of the carbon is absent, and providing always that the elements exist in the same condition in all cases. The common elements silicon, manganese and sulphur probably exist in the same condition in all cases, but in the example of phosphorus this does not exist in mild steel as the free phosphide eutectic. The influence of the former constituents in the quantities usually met with in industrial alloys on the ultimate strength values is practically negligible, thus confirming our previous notes on their intrinsic influence.

Indirect Influence of Other Elements.

When one considers these elements and their influence on the ultimate strength, properties as a result of their influence on the condition of the carbon contents, the general conclusion that, other things being equal, those elements which tend to increase the percentage of carbon in the graphitic

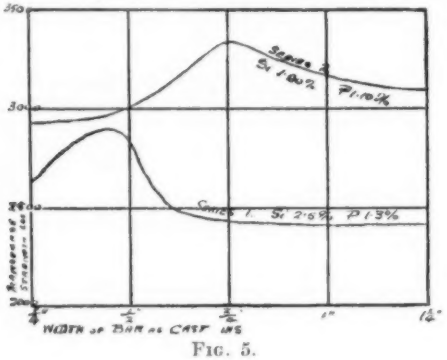


FIG. 5.

state lower the ultimate strength values and *vice versa* can be amply substantiated by experiment.

It is generally considered, although this has not been definitely experimentally established, that under any given set of conditions there is a type of critical composition of a grey iron, which gives the maximum ultimate breaking strength results. This composition is considered to be such that under the conditions of casting the final structure is one containing no free ferrite, but all pearlite and graphite. This is the basis of the now fairly well known general method of attacking the problem of the production of high strength cast iron from the point of view of chemical composition. This method consists essentially of the reduction of the silicon to such proportions that under the particular conditions of casting the extent of the graphite formed is just sufficient to leave the whole of the combined carbon existing as pearlite. At the same time the phosphorus and sulphur contents are reduced to their lowest value with the object of reducing the extent of the free brittle constituents present.

Total Carbon.

Considering the relative breaking strengths of steel and ordinary cast iron, it would at once be expected that any reduction in the total carbon content of cast iron which is in effect tending to make the cast iron more nearly approach the nature of steel would have a concomitant influence in increasing the ultimate strength values. This expectation has been repeatedly justified by experiment, and modern development in high tensile strength cast iron has a distinct tendency to adopt those methods of preparation in which the reduction in the total carbon contents can be successfully accomplished.

Casting and Cooling Conditions.

The influence of the rate of cooling, which in the practical mind's eye is regarded as the cross-sectional thickness of the casting, on the condition of the carbon is well understood. These conditions, for this reason, have a profound influence on the ultimate strength values, and has been demonstrated on many occasions by various investigators. Of these investigations, two comparatively recent ones are of considerable importance, viz., Beeny*[1] and Russell*[2]. Both these experiments were carried out on bars of varying cross section of the same chemical composition of metal. These results are platted in the form of curves, and are illustrated in Figs. 4 and 5.

The evidence which such experiments as these afford on the necessity for some standard form of test bar need not be emphasised here. The necessity for this is very generally recognised, and most recent specifications contain some provisions relating to the dimensions of the castings from which the test pieces are to be taken.

The most important feature of the above experiments is the definite evidence of some critical dimension for a given composition of cast iron at which the maximum ultimate strength value is obtained. Such a critical point has long been suspected, and evidence of this is to be found in the researches of other workers both in connection with cast iron and other cast alloys. In a series of admirable microphotographs Mr. Beeny is able to show the characteristic structural differences in the size and arrangement of the graphite and phosphide constituents between the high and the low strength values.

It is of considerable importance to notice that the ratio of combined to free carbon in the specimen is not appreciably altered within the limits of rate of cooling or the differences in cross-sectional dimensions adopted. Whatever variation there is in the condition of the carbon, it bears no relation to the strength variations. It is to be hoped that these investigators will continue these experiments, which are of vast importance.

Casting Temperature.

Since the classical experiments of Longmuir on the influence of casting temperature considerable work has been done on the influence of this feature on the ultimate strength properties of cast iron. In his experiments, Longmuir found that there was a certain range of casting temperature which gave the highest ultimate strength for the particular composition and size of casting adopted. Both above and below this temperature value the ultimate strength showed a lower result.

Longmuir's experiments were not strictly confirmed by Hatfield, and there is still some confusion of ideas as to the exact influence of the casting temperature.

Some early experiments of the author's‡ confirmed Longmuir's results. The work of Hailstone† is of considerable interest in this connection. Starting from a fairly high casting temperature of 1,428 deg. C., Hailstone found a steady fall in the ultimate strength value from 10.98 tons per sq. in. to 5.24 tons per sq. in. with a casting temperature of 1,264 deg. C. In this respect Hailstone's work is more in accordance with the results obtained by Dr. Hatfield. It is of interest to draw attention to the fact that the higher the casting temperature the higher the combined carbon contents.

The exact mechanism of the influence of the casting temperature is in all probability exerted through its influence on the rate of cooling, and it is probably a fact that the higher the casting temperature the higher the actual rate of cooling. It would be anticipated from what has been said with regard to rate of cooling that something of the nature of a critical casting temperature would be expected for a given composition and sectional dimensions of casting.

(To be continued.)

IN CONSEQUENCE of the decision of Dorman, Long & Company, Limited, to appeal against the rateable value of their Redcar works, the Gisborough Board of Guardians has decided to make a new valuation of the property.

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* [1] I.B.F., 1924.
* [2] F.T.J., Sept. 27, 1923.
‡ Proc. M/c Assoc. of Engineers, 1916.
† J.I.S.I., 1916, Carnegie Memoirs.

Heat-Resisting Cast Iron.*

By ANDRÉ LEVI, Director of the St. Nicolas Ironworks and Foundries, Professor of the Foundry High School, Paris.

During the last twenty years the influence of temperature on cast iron has been made the subject of numerous Papers and researches. The greater part of these Papers may be described as theoretical research, the object sought being to determine the action of temperature on the physical properties of cast iron, and above all to explain the causes which bring about the modification of these properties.

It seems desirable to review the principal works touching on this question, with the object of arriving at conclusions of a practical character. As a large number of castings have to be submitted to high temperature and resist its effect, it is thought that an examination of such works may yield certain indications and enable manufacturing formulæ to be embodied forthwith—formulæ of interest both to the practical worker and the foundry manager.

The well-known works of MM. Charpy and Grenet have established the fact that under the action of heat grey cast iron undergoes a permanent, non-reversible increase in volume.

These workers showed that this increase was due to a graphite deposit resulting from the decomposition of the cementite $Fe_3C = 3\,Fe$ + graphite. They also proved that this reaction took place by heating even *below* the lowest critical point, *i.e.*, at temperatures below 725 deg. C. As regards a particular kind of cast iron, the amount of this increase in volume is the greater, the slower the heating. With a constant heating speed the rapidity of the phenomenon increases in proportion to the amount of silicon in the iron.

This is tantamount to saying that the annealing of the metal is accompanied by an increase in volume due to the formation of graphite. Nevertheless, it has been observed that the augmentation in volume in the course of successive heatings and coolings is much greater than the increase which may result from annealing and the decomposition alone of Fe_3C.

Outerbridge's Conclusions.

In 1904 Outerbridge[1] conducted a series of tests with cast-iron bars heated and cooled several times in the electric furnace. These experiments led him to formulate the following conclusions:—

(1) The increase in volume and also the expansion are not indefinite. After each heating operation the expansions appear in diminishing ratio and cease altogether after a certain number of heats.

(2) The coefficient of dilatation in a metal subjected to repeated heat tests does not remain constant. It may reach a value lower than half the coefficient of dilatation in an untreated metal.

(3) A heating, even if prolonged, produces no effect unless it is followed by cooling.

(4) The increase of volume corresponds to a decrease in specific gravity. In the course of his tests Outerbridge found that after 16 successive heats this specific gravity had changed from 7.13 to 6.86, that is, a decrease of nearly 4 per cent.

(5) In continuing his tests on thin plates heated by the Bunsen burner, he similarly found an increase of weight.

(6) A microscopic examination of these plates showed the existence, after treatment, of a series of cracks which would render the plates permeable to water and air.

The two experiments described below, which are particularly striking, enabled Outerbridge to illustrate practically the phenomenon he had studied.

To show the different action of temperature on cast iron and steel, Outerbridge subjected to repeated heats a steel tube into which he poured a cast-iron plug. After a few heats the steel tube *was broken* by the swelling of the cast iron. A second tube of wrought iron was filled with molten cast iron and the two ends were planed level. After three heats it was found that the iron was projecting from the tube at each end owing to its having swollen.

Resuming his tests in 1908, Outerbridge[2] succeeded in getting the specific gravity of cast iron to fall from 7.13 to 6.01, which is equivalent to a decrease of nearly 13 per cent.

He points out, moreover, that the phenomenon of increase of volume appears to be more rapid in *soft* metal than in hard. With metal containing 0.5 per cent. combined carbon, he obtained an increased volume of 40 per cent. with 100 repeated heats at 650 deg., the same result being obtained with this metal after 27 heats at 790 deg.

To sum up, the work of Charpy, Grenet and Outerbridge appears to prove that the increase in volume is produced by repeated heats only if they are followed by cooling; that this phenomenon occurs even at temperatures below 725 deg.; that it is followed by a decrease in specific gravity and by an increase in weight of the sample; and that it invariably causes the formation of fissures, which produce porosity in the sample treated. It is necessary to note that in no case can the decomposition of the cementite alone explain the increase in volume by 40 per cent. found by Outerbridge.

For this reason he is disposed to attribute this phenomenon to the action of the occluded gases in the metal. He supposes that these gases undergo at high temperatures an expansion which in turn produces a permanent expansion of the minute cavities in which they are confined. This expansion would produce in the metal the porosity and the apparent increase in volume which have been described above.

The Work of Rugan and Carpenter.

Outerbridge's tests were resumed in 1908 and 1911 by Rugan and Carpenter. Without entering into the details of the experiments carried out by these authors, their conclusions are summarised: (1) In agreement with Outerbridge, Rugan and Carpenter find that the increase in volume does not occur unless the sample is subjected to alternate heatings and coolings. Heating alone does not cause an increase in volume; (2) various tests showed that the extent of the increased volume is a function of the chemical composition of the metal. The increased volume found in three different metals varies from 35 to 38 per cent., and remains constant after about a hundred heats; (3) only grey cast irons show this phenomenon. The presence of graphite is therefore regarded as *an indispensable element* in increasing the volume; (4) increases of volume are augmented by an increase in the silicon content, and this takes place almost in proportion to the content of that element; (5) only a part of this increase in volume can be attributed to the annealing of Fe_3C; (6) increases of weight take a course approximately similar to that of the volume; (7) the greater the Si content, the greater is the final increase in weight; (8) the authors consider that they have thus demonstrated that increases in weight and volume are solely due to phenomena of oxidation, which operate specially on the free carbon, the silicon, the iron, and particularly on the silico-ferrite; and (9) microscopic examination shows that this oxidation takes place very specially along the lamellæ of graphite, which finally disappears entirely.

The increase in volume is said to be due to four causes: To the partial oxidation of the Gr (which phenomenon diminishes when Si increases and disappears entirely when Si = 6 per cent.); to the probable oxidation of the Si existing in the form of silico-ferrite causing the formation of Fe + SiO_2; to the oxidation of the iron uncombined with silicon; and finally, to a slight extent, to the expansion of the hydrogen, occluded in the metal. To sum up, Rugan and Carpenter consider that it is primarily a question of process of oxidation.

In a second monograph (1911) the same writers

* A Paper read before the Glasgow Conference of the Institute of British Foundrymen on behalf of the Association Technique de Fonderie.

[1] "Engineering," 1904.

[2] "Iron Age."

seek to examine the influence of the different elements on the phenomenon of expansion. They admit, as the result of these tests, that phosphorus slightly diminishes the increase of volume, that the presence of manganese retards it considerably, and that sulphur is without influence.

Finally, as regards the action of the occluded gases, these writers consider that this action is negligible in regard to metals containing more than 3 per cent. silicon. On the other hand, with Si between 1.75 and 3 per cent., the action of the gases would effect an expansion of 1 to 2 per cent. When the silicon is below 1 per cent. the increased volume due to the action of the gases would amount to 10 per cent. of the total increased volume.

While making certain reservations as regards the ascription of the expansion to phenomena of oxidation (as will be seen later, this point has been strongly contested), the author retains the experimental fact which appears to him to stand out from the tests of Rugan and Carpenter: The elements which favour the formation of graphite accelerate the phenomenon of increase in volume; those which oppose this formation retard its occurrence. This first conclusion, which the author had already formulated in 1923,[3] has been confirmed by experimental researches made by Andrew and Hyman, which will be examined later.

It may be assumed forthwith that the proportionality between the Si-content and the expansion of the metal, established by Rugan and Carpenter, would be attributable rather to the property of the Si in promoting the formation of graphite than to the chemical properties themselves of that element. In fact, the penetration of the air into the mass of the metal will be all the easier in proportion as the number and the dimensions of the graphite lamellae are greater.

The experiments examined above, and, moreover, most of those carried out later by various workers, have all reference to the action on the metal of temperatures comprised between 650 and 850 deg. C., that is to say, approximate to or above the transformation points.

Before proceeding to examine these experiments, it appears interesting to analyse a study dealing with the action of superheated steam on cast iron, that is, with the effect of relatively low temperatures, 425 to 500 deg. C.

A very complete study of this question has been made by Campbell and Glassford.[4]

These writers, having observed the rapid corrosion of iron casting subjected to the action of superheated steam—a corrosion accompanied by an increase in volume—sought to determine: (1) The nature of (the) corrosion; (2) Why certain metals do not corrode; and (3) what must be done to prevent its occurence.

It may be noted, moreover, that Rugan and Carpenter had already found that cocks plunged into superheated steam at 360 deg. expanded, but they considered that this phenomenon was different from that of expansion at a high temperature. The work of Campbell and Glassford, however, appears to the author to bring out certain very interesting resemblances between these two phenomena. A first study consists of a micrographic examination of a dome-cock and flange which has been in use on the discharge side of the superheater of a separate furnace for two years. It shows considerable structural modifications in the metal.

In the first place, a thin coating of oxide is formed round the particles of graphite; then there are crevices which become wider and wider; finally, as the parts in direct contact with the steam are approached, the formation of a mixture of oxides and graphite is found, constituting a powdery mass devoid of strength.

This first examination, then, indicates progressive oxidation process of a very pronounced character, which takes place along the graphite lamellae.

Campbell and Glassford's Findings.

In studying the same phenomenon on bars subjected to the action of superheated steam (6.75 kg. (14.85 lbs.) at 425 deg C. for 30 days at first, then 90 days afterwards) Campbell and Glassford came to the following conclusions:—

(1) Under the action of steam, samples of white cast iron, steel and malleable cast iron show only one and the same type of oxidation. The samples have a skin regularly oxidised, to a very slight depth, and the oxide fills uniformly all the crevices which may exist on the surface of the sample.

(2) Under the same treatment samples of grey cast iron containing less than 1 per cent. Si show superficial oxidation similar to the specimens of white cast iron or steel, but in addition a slight penetration of oxides following the largest plates of graphite is found.

(3) With Si between 1.25 and 2.50 per cent. there are the same appearances, but the penetration of the oxidation appears to grow with the increase of the silicon content and extends in depth.

The authors appear to conclude, therefore, with Rugan and Carpenter that the processes of oxidation increase proportionally with the increase of Si. In closing, however, they make one remark which is considered especially important:—

"It appears natural," they observe, "to conclude that the increase of the silicon content is related to the increased corrosion. Yet the very good resistance of a sample containing 2 per cent. Si might justify another conclusion, viz., that *the finer the graphite lamellae are, the less is the corrosion.* This conclusion is in accordance with practical experience, which shows that good gun iron (grey special cast iron) with 2 per cent. Si and Gr low) resists the action of superheated steam very well." In short, the two last researches appear to indicate that the increase in volume is due to a process of corrosion, that is to say, oxidation.

Okochi and Sato's Views.

Quite another point of view has since been advanced by certain Japanese scientists, whose work it is proposed to examine.[5]

A first investigation was carried out by Professors Okochi and Sato, the expansion curves being taken by means of the Chevenard dilatometer.

The following were the principal conclusions reached as a result of these tests: (1) The influence of oxidation is of little importance in regard to the increase in volume; (2) the expansion, during the first heat, is due to the decomposition of Fe_3C; (3) during the repeated heating and cooling, after the former the increase takes place twice: (*a*) At the point Ac; (*b*) at the higher temperatures; and (4) the increase at the point Ac (about 815 deg.) is due to the effect *caused by the pressure of the occluded gases* in relation to the contraction[6] accompanying the transformation Ac during the reheating, and the increase at the higher temperatures is due to the fact that the metal yields to the pressure of these occluded gases.

In order to accept this explanation, which approximates to that of Outerbridge, it must at the same time be admitted that the metal is not permeable to gas at high temperatures. Otherwise those gases would escape before causing an increase in volume. It would have to be admitted likewise that, inversely, the gases may penetrate the metal at low temperatures—this in order to explain the increases in volume following the further heats

Kikuta's Hypothesis.

Mr. Tario Kikuta undertook certain experiments intended to verify this hypothesis. He made a first series of tests for the purpose of measuring the velocity of the passage of air through a hollow cast-iron cylinder, the temperature of which was progressively raised. These permeability tests showed:—

(1) That the velocity of the passage of air through a hollow cylinder increases up to 600 deg. C. and then diminishes slightly, and (2) that the velocity of the passage of air is almost constant at the different temperatures, and is so up to 900

[3] "La Fonderie Moderne," April and November, 1923.

[4] Eighth Congress on Testing Methods, "Revue de Metallurgie," 1912.

[5] See the Communication to the Liège Congress (1922) by Mr. Tario Kikuta.

[6] It may be remembered that when a cast iron bar is heated it expands regularly to the point Ac (about 815 deg.); at this moment a sharp contraction takes place, whereupon the expansion continues, following a regular curve. In cooling, the bar contracts regularly to the point Ar (about 725 deg.). At this point a sharp expansion takes place, after which contraction continues regularly.

deg. After 34 heats this velocity decreases very slightly.

A second series of tests carried out on bars heated *in vacuo* showed that *these bars increased regularly in volume*. The two series of tests led Kikuta to reject the explanation of Okochi and Sato, as also that of Rugan and Carpenter, since no oxidation is possible *in vacuo*. To explain the increase in volume observed, he formulated a very ingenious theory which very well explains the cause of the formation of crevices and fissures noted by the preceding observers. The following is a summary: In the course of heating the expanding metal undergoes a sharp contraction at the point Ac; likewise, in the course of cooling and the shrinkage which accompanies it, a sharp expansion occurs at the point Ar. Now the metal is not a homogeneous substance, the distribution of the graphite being irregular: there are thick plates at certain points with thin lamellæ close beside them. The contraction and expansions which occur at the Ac and Ar points, and which are due to the dissolution and deposit of a certain quantity of free carbon, are very different in extent according as they are produced in the neighbourhood of thick or thin plates of graphite. The result is very considerable tensions at the different points of one and the same sample of metal. It is to these tensions, the action of which is specially apparent in the vicinity of the graphite plates forming acute angled fissures in the metal, that Kikuta attributes the phenomenon of increase in volume.

He expresses his conclusions as follows: The continuous expansion of grey cast iron *in vacuo* during the repeated heatings and coolings is due to *the differential expansion, to the different micro-proportions of the sample which produce numerous fissures or cavities in the neighbourhood of the plates of graphite.*

Moreover, he adds that: "In an oxidising atmosphere the expansion *is* accelerated by the oxides which are formed and which fill up the fissures or cavities originated during the Ar transformation." The action of oxidation on the increase of volume—contrary to what is accepted by Rugan and Carpenter—would therefore appear to be a secondary and indirect action.

It may be noted, however, that if this theory is capable of explaining the increase in volume by heating at 725 deg. C. or above, it does not in any way explain the increase in volume at the temperature of 425 deg., as studied by Campbell and Glassford. For, even admitting that the action of the superheated steam gives rise to phenomena essentially different from those accompanying a heat at 725 deg., it is nevertheless the case that a very marked increase in volume may be due solely to oxidation processes.

Nevertheless, the result of certain experiments by Portevin on the effects of hardening in grey cast iron appears to confirm Kikuta's theory to some extent. These observations relate to a study by Durand of the thermal treatment of cast iron[7]. As apparently the thermal treatment of cast iron (hardening followed by tempering and annealing) should prove of practical interest, it is thought well to dwell for a moment on this question, certain aspects of which fall within the general scope of the present study.

The work of Charpy and Grenet, as also that of Howe, has led a large number of scientists to consider that cast iron is constituted, from the point of view of structure, like a mixture of steel and graphite. From this view it follows directly that the properties of the metal will depend, on the one hand, on the composition or the shade (mild, medium, hard) of the constituent steel, and, on the other hand, on the quantity, dimensions and form of the graphite lamellæ disseminated throughout this steel; the latter play the part of inclusion, which inclusion causes in a very marked fashion a diminution in the mechanical properties of the constituent steel.

This view being accepted, Durand draws from it the following conclusions: Since the thermal treatment—the annealing, hardening and tempering of a steel—improves the mechanical properties very perceptibly, there is every reason to believe that the same treatment applied to cast iron should have the effect of improving the characteristics of its matrix of steel in a similar manner, and consequently those of the metal as a whole. The experiments made by Durand gave him the following results:—

Annealing carried out at a temperature of 900 deg. on test bars of grey cast iron shows that the treatment diminishes the tensile strength by about 30 to 40 per cent. The mean breaking stress after annealing remains practically constant, but the total breaking load is decreased by about 20 per cent., this fact being attributed by Durand to the graphite separation accompanying the annealing, which separation, in fact, he worked out by analysis. On the other hand, in dealing with test bars which had been oil-hardened and afterwards tempered, he obtained an increase of tensile strength amounting to as much as 30 per cent. of the initial strength, and in certain metals an increase of over 40 per cent. in the height of drop. (After treatment the strength rose from 23 to 30 kg./cm.^{2}, and the height of drop from 65 cm. to 1.10 m.) (Technical specification of the French railways for shock tests.) This tensile increase is particularly marked after treatment in the case of metals having CC equal to about 0.60 per cent.

It may be noted that the metals tested had approximately the following composition: Gr., 2.70; CC, 0.50; Si., 1.18; Mn., 0.5; S., 0.04; and P., 0.2 per cent.

These tests confirm clearly the correctness of the view of Charpy, Grenet and Howe as to the composition of cast iron. It should be noted, however, that the experiments in question were carried out on test bars.

In discussing these experiments and their possible applications in the treatment of semi-steel cast-iron projectiles, Portevin points out that a large number of tests made on these projectiles have shown that any hardening followed by tempering rendered the projectiles porous. Certain shells subjected to the treatment increased in volume and were no longer fit to stand the specification compression test required by the Artillery. On being rung they gave a dull sound, an indication of defective mechanical properties. These defects were more accentuated by water hardening than by a milder hardening with oil.

It is reasonable to suppose that the hardening of a steel matrix enfeebled by graphite plates frequently forming an acute angle will produce blow-holes. All grey cast iron, however, is comparable to such a matrix. It is also evident that these blow-holes will be more pronounced in proportion to the thoroughness of the hardening, that is, they will be larger with water hardening than with oil hardening. These phenomena appear to be in every way comparable to the hardening blow-holes to be found in every steel casting which shows acute angles.

These observations appear specially designed to strengthen Kikuta's hypothesis, the hardening producing more markedly the same effect as the processes of internal tension to which he ascribes the expansion of the metal. In closing, Portevin[8] appears to favour the rejection of hardening followed by tempering cast iron.

In a second monograph Durand, returning to the question, points out that the increase in volume may be limited by the decrease of the silicon content in the metal treated and also by restricting the heat period—which is in accordance with the tests of Charpy and Grenet already quoted.

From an examination of the experiments summarised above, contradictory as their results may be, the following points nevertheless appear to stand out very clearly:—

(1) The increase in volume, which is found after a first heat followed by cooling, is incontestably due to the process of graphitisation, that is, to decomposition of the cementite $Fe_3C = 3\ Fe +$ graphite.

(2) The subsequent increase in volume is due both to the process of oxidation and to the action of internal stresses produced at the point Ar, this latter cause being evident after the heat tests *in vacuo* carried out by Kikuta and confirmed by the observations of Portevin on the effects of

[7] Report to the Académie des Sciences, 1922.

[8] Report to the Académie des Sciences, 1922.

hardening (internal blow holes along the graphite lamellæ).

The author is, however, unable to agree with Kikuta to the entire rejection of the conclusions of Rugan and Carpenter with regard to the influence of oxidation on the increase of volume. The tests of Campbell and Glassford show incontestably that the oxidising action of the steam at temperatures not exceeding 425 deg. may produce a considerable increase of volume. It is evident, however, that in this case, the temperature being markedly below the critical point, Kikuta's hypothesis is not applicable. Therefore oxidation alone may, in certain cases, produce expansion.

Moreover, it was by heats at 650 deg. (that is, below Ar) that Outerbridge obtained increases of volume amounting to as much as 40 per cent. of the initial volume.

It is admitted that the two causes (oxidation and internal tension) act simultaneously, without, however, expressing an opinion on the relative influence of each of them upon the final increase of volume.

But, while admitting with Rugan and Carpenter the effect of oxidation, it is not thought that this process is, as they state, directly proportionate to the silicon content as a result of the rapid oxidation of the silico-ferrite.

As the author already stated in 1923[9], he still thinks that this proportionality is due, not to the presence of the silicon iself, but to its property of precipitating the graphite. Even at that time he considered that if, as Rugan and Carpenter find, metals with 1 per cent. Si increase in volume less than those with 2 per cent., this is because, with the increase of Si, there is produced an increase, not only of the quantity of graphite, but also and in particular an increase in the dimensions of the lamellæ of that element. Now, it is evident that the larger the graphite lamellæ are, the more the processes of oxidation due to penetration of the oxygen along these lamellæ will be facilitated on the one hand, and, on the other hand, the more apparent will be the effect of the internal stresses produced by the heat. This, moreover, is admitted by Kikuta.

The fact of the feeble oxidation of gun iron even when it contains 2 per cent. Si, which is noted by Campbell and Glassford, in itself confirms this hypothesis.

Now, if this hypothesis is accurate, it is evident that all the elements which, like silicon, precipitate graphite at the same time promote the increase of volume, and that, on the other hand, those elements which oppose the formation of graphite must retard that process. This is confirmed by work carried out subsequent to 1923 by Messrs. Andrew and Hyman[10] and by Mr. Donaldson.[11]

Influence of Elements on Growth.

Mr. Donaldson, in studying the action of repeated heats at 450 and 500 deg. C. on cast iron of different compositions, found that while chromium and manganese reduce the diminution in tensile, after heating, the addition of nickel (an element whch precipitates graphite) has a contrary effect. After heating for 120 hours at 450 deg. C. he found a diminution of tensile strength of 7 per cent. in ordinary grey cast iron, of 6 per cent. in the same metal containing 2.43 per cent. Mn., of 5.5 per cent. with 0.39 Cr, and of 12 per cent. with an addition of 0.75 per cent. of nickel.

Andrew and Hyman, in making tests with repeated heats at 900 deg. C., reached similar conclusions, which they formulate as follows:—

Nickel and aluminium, acting like silicon, promote an increase in volume, and this not because these elements are specially oxidisable, but because they promote the formaton and the expansion of the graphite lamellæ. As regards chromium, it reduces expansion considerably without entirely preventing it. As a sequel to the examination of the work summarised above and as a result of the author's personal experience, he thinks he may finally formulate the following conclusions:—Cast irons subjected to repeated heats and coolings at temperatures not exceeding 900 deg. undergo an increase in volume accompanied by a diminution of all their mechanical characteristics. The increased volume following the first heat is due to decomposition of the cementite: $Fe_3C = Fe + Gr$.

The subsequent increases in volume are due to the combined effect of internal oxidation and the formation of fissures caused by the considerable stresses produced in the metal at the Ar and Ac points. The extent of these volume increases is dependent on the size and form of the graphite lamellæ contained in the metal.

Consequently, all those elements which favour the formation and agglomeration of graphite lessen the resistance of the metal to high temperatures. The action of those elements which form stable carbides, on the other hand, is unfavourable to the increase of volume in question. In the manufacture of heat-resisting cast iron it is desirable in practice to obtain in particular: (1) *A high Mn or Cr content* (about 0.40 Cr), these elements forming stable carbides which resist annealing. These carbides are of the type $(Fe\ Mn)_3\ C$. Their stability retards increase of volume subsequent to the first heat; (2) *a reduction of the amount of graphite by every possible means*; (3) *the formation of round graphite nodules and not of acute-angled lamellæ*, and (4) a judicious selection of elements such as Si, Mn, Cr and total carbon in order to secure the conditions set forth above, in a manner suitable for the ultimate purpose of castings required to withstand the effect of high temperatures.

Here it may be pointed out that cast irons low in total carbon have normally a very fine grain, and that on microscopic examination they show a highly divided graphite formed of very fine or curved lamellæ, or of round nodules. This type of structure is frequent in semi-steel cast iron with high steel content (25 to 30 per cent.), and particularly in cold- or semi-cold-blast metal. Moreover, it may be pointed out that this type of metal (total carbon low) may be obtained with a relatively high Si content, 2 per cent. or more. The result is that with a suitable admixture of silicon low total carbon can be obtained, while maintaining the combined carbon in the neighbourhood of 0.6 per cent. and even less.

Having made these remarks, it seems dosirable to examine some particular cases of castings required to resist high temperatures, and let us see what compositions appear most desirable for such castings, taking as basis the theoretical conclusions we have formulated above.

It should be stated, however, that although these compositions are derived from theoretical reasoning, they have nevertheless been verified by the author in the manufacture of various articles and checked on castings which have given satisfaction in use.

Cast crucibles for containing lead baths, for hardening or tempering, or for melting alloys or white metals.

Here it is a question of castings which are generally heated by town gas in an atmosphere which is generally oxidising, and in direct contact with the flame. These castings are seldom perished by fusion (the heating temperatures being between 500 deg. and 600 deg. maximum), but usually by porosity. It may be observed that these castings have not to withstand any sort of mechanical stress, and that they generally remain rough foundry castings.

Under these conditions two formulæ may be applied: (1) White cast iron or white mottled iron with high manganese content to prevent any possibility of graphitisation, the silicon being kept low for the same reason; (2) semi-steel cast iron with low total-carbon content and low combined-carbon content, with a quantity of Mn sufficient to retard the graphitisation of this carbon, the S and P content being indifferent:—

T.C. < 3.0; CC < 0.5; Mn > 0.9; S, 0.15; P, 0.5 to 1.5; and Si > 2 per cent. A semi-steel cast iron with 25 per cent. steel with a ferro addition is quite suitable.

Thin grates for heating apparatus. The same composition with P increased to give fluidity, Si between 2 and 2.5 to prevent the formation of white cast iron, which would be too fragile:—

T.C. < 3.2; CC < 0.6; Mn, 0.9; S, 0.15; P, 1.5; and Si, 2 to 2.5 per cent.

Thick fire bars.—If the question of cost is not

[9] See "Fonderie Moderne," A.T.F. Conference.
[10] Iron and Steel Institute, 1924.
[11] "Foundry Trade Journal," 1924.

an obstacle, it is well to lessen the P content in order not to have too low a melting point. If the castings are liable to be perished by fusion the CC should be kept as low as possible :—

T.C. > 3.20; Mn, 0.7; P, 0.4 to 1.2; S, 0.15; and Si, 2.0 per cent.

It may be remarked that in all these castings the raising of the S content presents no disadvantage and is rather to be recommended, experience having proved that white or mottled cast iron with very high sulphur content resists the action of reheating very well.

Stoves, ranges, heating apparatus.—This type of castings must fulfil a series of almost contradictory conditions. As they are frequently enamelled, these castings have to undergo one or two heats, during which they are quickly brought to high temperatures. Progressive heating is rarely possible in this type of manufacture. This first heat and the necessity of avoiding excessive fragility, which would be very harmful during the manipulative stages through which these castings have to pass, render it impossible to obtain resistance to heat by the use of white or mottled cast iron, or even high percentage semi-steel. As these castings are also subjected to various machining operations (drilling), they have to be specially soft, particularly as their thickness seldom exceeds 3 to 4 mm. The limited thickness of these castings presents a danger in regard to fragility, but at the same time it necessitates the use of metal rich in phosphorus, as this element alone gives the metal the fluidity indispensable to the success of these castings.[12]

The same reasons which make it difficult to use semi-steel cast iron make it impossible to employ metals high in manganese or chromium.

In these circumstances, therefore, it appears difficult to embody the formula for a good heat-resisting cast iron, viz., the least amount of graphite possible with very low combined carbon. The solution may, however, be reached by another method. It is known that the size of the graphite lamellæ and consequently the grain of the metal increase with the increase of the Si content between 1 and 2.5 per cent. Si. But when in the neighbourhood of 2.5 per cent. nearly all the carbon is precipitated in the form of graphite, any further increase of silicon produces an inverse effect. The CC still remains low, but the total carbon content diminishes very rapidly. This total carbon being almost entirely in the state of graphite, with the increase of Si the lamellæ of the graphite are seen to become smaller and smaller and less numerous. *Pari passu* the grain of the metal becomes more compact until, as everyone has observed, a metal with 4.5 per cent. Si shows a grain indistinguishable from that of mottled cast iron, and a 10 per cent. ferro silicon has the appearance of white cast iron.

The author considers that in the case being dealt with (cast iron for stoves, etc.) it is desirable to take advantage of this property of silicon in order to lower simultaneously the CC and T.C. contents. He therefore recommends the following formula :—T.C. < 3.2; CC low; Si, 2.8 to 3.3; Mn < 0.4; S, 0.15, and P, 1 to 1.5 per cent.

This composition differs materially from the formulæ recommended by many specialists, both French and English. Many recommend a Si content of about 2.20 per cent. Nevertheless, the theoretical considerations which have been advanced in the present Paper and manufacturing tests carried out on a large scale have confirmed us in our opinion, and we recommend the above formula for all stove castings, whether enamelled or not.

Metal for Diesel motor castings.—For this type of casting practice appears entirely to confirm the theoretical results which have been described. It must be remembered that these castings have to stand great mechanical stresses while working in certain cases (pistons) at temperatures approximating to and sometimes above 650 deg. C. For these castings, therefore, the author recommends the use of semi-steel cast iron with high Mn content :—

T.C. < 3.2; Si, 1.8 to 2; Mn > 1.0; S < 0.10, and P < 0.30 per cent.

A slight amount of Cr (about 0.3) could not but prove beneficial. The author also considers that a P content below 0.3 is essential to obtain the maximum shock resistance. Professor Campion[13] has shown that the lowering of tensile resistance between 0 and 500 deg. is sensibly less with semi-steel cast iron than with ordinary cast iron. He is consequently inclined to employ semi-steel cast iron for Diesel motor castings. The author's conclusions agree with his on this point. The author thinks, however, that in the absence of Cr, the Si content should be kept between 1.8 and 2 in order to lessen the quantity of combined carbon, and not between 1 and 1.5 as is done in the case of semi-steel cast iron for shells.

Cast Iron which has to Undergo Normalising Annealing.—Certain castings, such as the water jackets of valveless motors, etc., are sometimes subjected to a normalising annealing for the purpose of neutralising the internal stresses and preventing possible deformations when working. In this case the castings undergo only one heat. According to what has been already said, the increase of volume, as also the porosity and the lessening of resistance which arise from it, can only be due to the annealing of the combined carbon. It is therefore well to keep to temperatures sensibly below 725 deg. in the course of this annealing. Moreover, the author advises starting with a metal having as low a combined carbon content as possible. This can be obtained very easily with a Si content equal to or above 2 per cent., according to the thickness of the castings.

Castings which have to Undergo Thermal Treatment.—As Durand has shown, oil-hardening at 850 deg., followed by tempering at 600 deg., can improve very materially the mechanical properties of certain cast irons. This treatment, however, does not appear desirable in the case of castings which have to stand high pressures. In all such cases, in order to prevent the increase in volume and the inconveniences resulting from it, it is necessary to reduce the heat period to the minimum. It is here unnecessary to seek to reduce the combined carbon content. As only the metals with combined carbon above 0.50 are capable of having their mechanical properties improved by this treatment, the author recommends for the purpose in question cast iron of the following composition :—T.C. < 3.3; CC > 0.5; Si < 1.20; Mn, 0.6; S < 0.10; and P < 0.3 per cent.

Castings having to Stand very High Temperatures approximating to the Melting Point of the Metal.—The considerations advanced in the present monograph do not apply to this type of casting, with regard to which the problem consists particularly in obtaining a product having a melting point as high as possible. The metal being regarded as a steel containing graphite lamellæ in a state of inclusion, it will at once be deduced that the melting point of the metal will be the higher in proportion as the steel constituting its matrix is soft. With the same object the sulphur and phosphorus will be eliminated. It is known, moreover, that graphite is in itself a refractory element, however slight its agglomeration, but that it burns fairly easily when it is in the state of extremely divided particles.[14]

It is for these reasons that it is desirable for this type of castings to get soft cast iron with low S and P contents, with combined carbon very low, and with the graphite formed of lamellæ as wide and thick as possible.

In closing this monograph the author desires to emphasise the fact that the formulæ given do not constitute a restrictive whole. They are not the only good formulæ, but represent merely one

[12] The Author considers it well to keep the phosphorus content between 1 and 1.5 per cent. Above 1.5 per cent. the phosphorus, without increasing the fluidity of the metal materially, renders it extremely fragile. Experiments made on an industrial scale showed that thin castings with 2 per cent. P gave so much wastage from breakage in handling that it was found desirable to lower the P by the addition of hematite cast iron. Notwithstanding the relatively high cost of the latter, there was found to be a decided advantage from the point of view of ultimate cost.

[13] "Foundry Trade Journal," May, 1924.

[14] This is the case in castings which have to be enamelled. The object of the preliminary annealing to which these castings are often subjected is to produce partial consumption of the graphite lying at their surface, the presence of which forms an obstacle to the proper adhesion of the enamel.

of the possible methods of obtaining heat-resisting cast iron.

He has here examined a series of scientific studies and sought to derive from them a general theory explaining the action of high temperatures on grey cast iron.

This theory has led us to adopt a certain number of compositions suitable for different types of castings which have to withstand the action of heat. The author finds, moreover, that the formulæ thus obtained agree generally with the results of practical and manufacturing tests. The greater number of them are no novelty, and have already been recommended by technical foundry authorities.

The foundry problems in regard to which a *general view* of this kind can be formulated are still extremely rare. The work of the foundry technical associations will without doubt serve rapidly to increase their number.

The author does not claim to exhaust such a complex question in the present Paper, but he would be happy if the examination and discussion of this work should serve to bring about, in the field of heat-resisting cast iron, a lasting agreement between metallurgical scientists and iron founders, for their well-considered collaboration appears to be more and more indispensable to all further progress in foundry work.

Gazette.

A WINDING-UP ORDER has been made against Minerals and Metals, Limited, 1, Queen Anne's Gate, Westminster, London, S.W.

MESSRS. R. L. HAYNE and H. C. CHINN, brass founders, etc., 10, Harp Alley, Farringdon Street, E.C.4, trading under the style of Chinn's, have dissolved partnership.

AT A MEETING of the creditors of the Redheugh Iron and Steel Company, Limited, in respect of which a winding-up order was made on May 12, the Official Receiver intimated that a statement of affairs had been prepared. It showed that there were unsecured creditors for £39,387. The assets were £12,167, which left a deficiency of £27,220. To that had to be added share capital amounting to £96,500, and the estimated total deficiency was £120,795. Failure was attributed to expenditure on extensions, loss through delay in completion of the extensions, loss through fall in prices due to trade depression and the heavy burden of taxation. It was resolved to apply to the Court to appoint Mr. T. C. Martin, of Milburn House, and Mr. J. William Armstrong, of Collingwood Street, as liquidators, and also a committee of inspection.

Personal.

THE HON. H. D. MCLAREN has been elected a director of John Brown & Company, Limited.

MR. A. CRAWFORD, who has died at Wishaw, aged 63 years, was formerly manager of the Glasgow Iron and Steel Company, Limited, Wishaw.

Wills.

ARNOLD, G., head of W. Arnold & Sons, agricultural and general engineers, Brandbridges	£69,889
BAIN, F. D., managing partner in the Redruth Tin Smelting Company and the Harford and Bristol Brass Company ...	£28,757

The Locomotive Industry.—At a meeting of the Committee on Industry and Trade evidence was given by Mr. C. N. Goodall, managing director of Robert Stephenson & Company, Limited, and Mr. A. Campbell, chairman of the Hunslet Engine Company, Limited, on behalf of the Locomotive Manufacturers' Association. The witnesses stated that the condition of the industry could only be regarded as desperate. The main factors that had brought about this state of things were: (*a*) The world-wide increase in the productive capacity at present devoted to locomotives. (*b*) The inadequacy of available markets to absorb such production. (*c*) The consequent ruthless competition, both internal and foreign, which in this country was rapidly exhausting the capital resources of the establishments engaged in locomotive manufacture. (*d*) The high costs of production in this country. (*e*) The absence of support from home railways such as would enable the industry to meet foreign competition on better terms.

Trade Talk.

THE BASSET COMPANY reports for 1924 a loss of 21,945 fcs., bringing up the total loss to 46,093 fcs. to date.

VIVIAN & SONS' copper works, Port Talbot, Glamorgan, will close down at the end of this month.

R. H. LONGBOTHAM & COMPANY, LIMITED, 22, Northumberland Avenue, W.C.2, have removed to Northwood, Middlesex.

JOSEPH KAYE & SONS, LIMITED, Lock Works, Leeds, have received a large contract from the Admiralty for the force-feed type of their serrated steel seamless oil feeders.

SIR W. G. ARMSTRONG, WHITWORTH & COMPANY, LIMITED, have now built locomotives for 29 distinct railway companies, and the average output reaches 55 main line engines a month.

A NEW RECORD has been set up by Cochrane & Sons, Limited, of the Ouse Shipbuilding yard at Selby, by the launching of thirty vessels since January. They have on order eleven trawlers to construct.

TO ENABLE the United Steel Companies, Limited, to keep their blast furnaces going, the Wellingborough Urban Council has reduced its royalties on ironstone taken from its land from 7d. to 3d per ton.

THE ANNUAL DINNER of the Engineers' Club will be held on Friday, October 23, at the Savoy Hotel, when the Rt. Hon. Winston S. Churchill, M.P., Chancellor of the Exchequer, will be the guest of the club.

A WINDING-UP PETITION has been presented against Cubitts' Engineering Company by the Earl of Dudley's Round Oak Works, Limited. The petition was heard at the Royal Courts of Justice on June 23.

ALFRED HICKMAN, LIMITED, are shortly closing their ironstone mines at Astrop, King's Sutton, near Banbury. Fifty per cent. of the men at the Hook Norton Mines will shortly be thrown out of employment, and the Oxfordshire Ironstone Company and other firms have already or are expected shortly to follow suit.

THE GLASGOW CORPORATION SUB-COMMITTEE have recommended acceptance of an offer by the Steel Company of Scotland for the supply of tram rails. Tenders by other English and Scottish firms were, it is understood, rather lower, but the sub-committee were of opinion that the contract should be placed locally.

PORTIONS OF THE ORDERS for rails placed by the London, Midland and Scottish Railway Company, mentioned in our last issue, have been secured by the following Teesside firms:—Dorman, Long & Company, Limited, Cargo Fleet Iron Company, Limited, Bolckow, Vaughan & Company, Limited, and Pease & Partners, Limited.

PALMERS SHIPBUILDING & IRON COMPANY, LIMITED, Jarrow, have booked an order for two moderate-sized vessels for the Anglo-American Oil Company, which will be built at their Amble yard, also an order for repairing the steamer "Demosthenes," about 12,000 tons, belonging to the Aberdeen Line, London, which will take three months.

THE CONSETT IRON COMPANY, LIMITED, do not propose to restart the large blast furnace until after the new steelworks have been operating for a time, and when the prospects of trade can be more accurately foreseen than at present. The Silica Brickworks at Templetown are being well employed, and the bricks and shapes that are being produced are establishing a reputation amongst coke-oven builders and gasworks and steelworks engineers. The silica bricks used in the construction of the new Fell Coke Works, which were manufactured at the Templetown Brickworks, have so far proved completely satisfactory, showing a perfect surface, and it is estimated their life will be much longer than that of any other material previously used in the industry. The construction of the new steelworks and rolling mills has made progress on the whole in a satisfactory manner. The steelworks will, it is expected, commence to operate experimentally during this month. Within the next few months the mills should be completely ready to begin the rolling of plates and sections. These will be started if the state of the steel trade, and particularly if the costs at which the company may find itself able to operate its new plant, are such as to justify this step.

Iron and Steel for the Balkan States.—The report recently circulated from Cologne that German merchants had entered into arrangements with foreign merchant firms with the object of jointly handling the merchant trade in the Balkan countries, is now contradicted. It had the effect of causing uneasiness among consumers in the Balkans. The consequence was that these customers, who had been in negotiation with German firms in regard to large transactions, broke off the discussions and placed their orders elsewhere. It appears that the report was based on a proposal of the Polish iron and steel industry to form a works association in German Upper Silesia.

(*Continued from page* 538.)

population was a very pressing one. If the city could only extend its boundaries right out into the country it would be able to prove helpful to the citizens. It would give the latter breathing space. The problem was a pressing one. At the moment it was being discussed in London, and indeed it was that circumstance which accounted for the absence of Lord-Provost Montgomery from the present function. In the course of his address

PROF. ANDRE LEVI.

Prof. André Levi is a director of the St. Nicolas Ironworks and Foundries, and Professor of the Foundry High School in Paris.

while proposing this toast Mr. R. O. Patterson, the Past-President of the Institute, had made some humorous reflections on the uncomfortable night he had spent in a city hotel alongside which the Glasgow tramcars seemed to run incessantly, and far from noiselessly. On that point he (Bailie McDougall) observed that the tramways manager in Glasgow was concerned not so much about the question of rubber wheels for tramcars as the rubber wheels of the competing omnibus. Personally, he did not think it was altogether a bad thing that they should have this keen competition on the streets of the city. Indeed, he rather welcomed the buses. It seemed to him that if the buses could give good service then in spite of all the Corporations in the world they would win eventually. If they could not, then the tramways would still continue to hold their own.

THE PRESIDENT announced that it had been necessary to make one or two adjustments on the toast list owing to the absence of invited guests. The toast of "The Foundry and Allied Industries" would now be proposed by Mr. H. Thomson Clark, manager of the "Glasgow Herald," and the reply would come from Sir Archibald McInnes Shaw and Bailie A. Ghogan, of the Central Ironmoulders' Association, Falkirk.

MR. H. THOMSON CLARK said since the knowledge had come to him that he was to propose this sentiment he had been trying to realise what the foundry trade in Glasgow and the kingdom really represented. He had been trying to analyse the word foundry, and if his assumption was correct as to its meaning then the foundry industry must be one of the key industries. Prince Henry, in a recent speech in Glasgow, had ventured to remark that Clyde labour was synonymous with excellence. Whether that reputation would be conceded by those from the other side of the Border he could not say, but apparently from the look of the audience when the haggis was brought those present appeared to be thoroughly appreciative of Scotland. (Laughter.) Then he understood that it was coming on to a period of 25 years since the Institute was founded. Knowing that circumstance as to their history, he would ask them to cast their minds back over the last quarter of a century. If they did so, then it seemed to him they would be able to appreciate the considerable advance that had been made in the foundry trade.

SIR ARCHIBALD MCINNES SHAW predicted that Mr. John Cameron would make one of the best presidents the Institute of British Foundrymen ever had. Although trade at the moment might be dull, they were not dispirited. But the dullness was not confined to the foundry and allied industries—it was dull in many other places. British foundrymen were a scientific body of men. They did not know in these difficult times whether they could make money or not, but if they could make good castings that was everything. The making of good castings was the one thing that worried foundrymen. Generally speaking, however, the British foundryman was a man of great resource. He knew the methods and processes of his trade, and he was consistently out for improvement. He was well aware that foreigners were trying to beat Britishers in many things, but he held tenaciously to the view that they would never beat Great Britain in foundrymen.

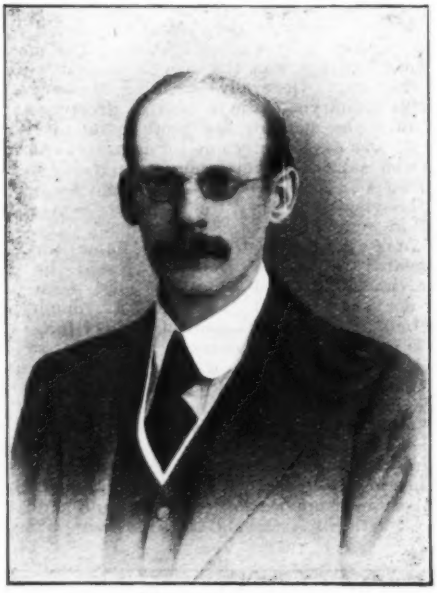
BAILIE A. G. LOGAN, whose name was also associated with the sentiment, said he had been a foundryman since he had been able to do anything at all. As a foundryman he took a pride in knowing everything that pertained to the foundry. Not only so but he felt proud of the fact that the workmen at all times seemed to take a pride in the work they were producing. If he knew anything at all of the aims of the Institute of British Foundrymen he should say that one of their chief objects and desires was to encourage training so that the production of output might be the best obtainable from the combined application of science and skill. He agreed with Sir Archibald McInnes Shaw in saying

MR. H. J. YOUNG.

Mr. H. J. Young was educated at King's College, London, and became associated with the Muntz Metal Company. Later he joined the late Professor Huntingdon, who had a very large metallurgical consulting practice. His first connection with iron-foundry practice was when he joined his present firm, The North-Eastern Marine Engineering Company, Limited, of Wallsend and Sunderland, as chief chemist. He was one of the originators of the Junior Section of the Newcastle Branch of the Institute of British Foundrymen.

that there was no danger from foreign competition in the foundry and allied trades so long as they had every means of applying research and scientific production, combined with the physical skill of the workers themselves. As Scotsmen, however, and as foundrymen they were proud of the fact that they were capable of turning out men who could go to the ends of the earth and carry on the industry. Falkirk, the centre of the light castings industry, produced more than eminent football players. It was a district that was capable of pro-

ducing very good castings. There was a feeling in certain circles that the Institute of British Foundrymen was an organisation that belonged to the employers. He had heard that remarked before, and he wanted to warn the members of the danger of such a feeling. It ought to be removed as soon as possible. Something ought to be done to show that the Institute welcomed all into its organisation, and the aim was to improve work and scientific foundry practice. If they could dispel that feeling, then Mr. John Cameron would



MR. A. CAMPION.

Mr. A. Campion was born in London, and received his general education at various schools in the City. His technical education was obtained at Finsbury Technical College and City and Guilds Technical Institute. He acted for some time as assistant to Prof. Herbert Macleod at the Royal Indian Engineering College. Mr. Campion's first industrial appointment was as chief chemist and metallurgist to the Steel Company of Scotland, Limited. Some four years later, in 1901, he was appointed principal assistant chemist and metallurgist to the Indian Government at Cooper's Hill. When Cooper's Hill closed, Mr. Campion carried on a private practice in Glasgow until, in May, 1909, he succeeded to the chair of Metallurgy in the Royal Technical College, Glasgow. In 1918 Mr. A. Campion became superintendent to the Foundry Technical Institute, which was instituted by the light ironfounding industry in Falkirk, for the prosecution of foundry research and education of foundry apprentices and workers. Trade depression led to the abandonment of the scheme in 1922, and Mr. Campion has since then been attached to the firm of Cameron & Robertson, Limited, Kirkintilloch.

have rendered, during his year of office, an inestimable service to the Institute of British Foundrymen.

The Toast of the Institute.

MR. JAMES WEIR thereafter proposed the toast of "The Institute of British Foundrymen." He explained that he had been asked by his brother, Lord Weir, to express his sincere regret at not being with them on the occasion of this banquet. Lord Weir had received an urgent call, which he could not see any way of avoiding, and personally he could assure the President that no one regretted the absence of Lord Weir more than he did. (Laughter.) He felt, however, he could adequately represent his brother in expressing appreciation of the Institute of British Foundrymen. The Institute was undoubtedly a vital and living force in the development of the industry with which it was associated. The art of casting metals was still far from being an exact science—in fact it was only emerging from the era of the domination of tradition and craft skill. So much the more important, therefore were the annual Conventions of the Institute in forming a clearing house of information, data, and experience, and in co-ordinating the allied sciences of metallurgy and engineering. Within his own experience he had seen the enormous progress which had been made in the technique of the industry, and in the elucidation of the underlying principles governing it. But they could not have failed to notice that no sooner had they solved the problems of to-day than the progress of engineering and the other industries which they served set still harder problems for to-morrow. The internal combustion engine, for example, with its extreme temperature gradients, had necessitated an entirely new type of practice and research. In fact, he personally thought it was not too much to say that the further progress of the internal combustion engine depended on the foundryman. On the other hand, the progress of aeronautics, with its dominant requirements of lightness, had equally given rise to new problems for the foundry calling for new methods of solution. In both of these fields of development their local branch had taken a worthy part. Indeed, in that connection he felt disposed to say that the Institute of British Foundrymen was to be congratulated on its progressive policy and its broad outlook. That was evidenced by the fact that papers had been exchanged with French, Belgian and American Societies. Thus they were keeping themselves in close touch with the progress which was being made in other countries. In addition to that they must keep in view the activities of the Cast Iron Research Association and the British Engineering Standards Association. Of course if an enlightened and progressive policy were all that were necessary their industry would, indeed, be in a happy state. Unfortunately, however, good castings were only a means to an end. They shared with the rest of the industries the severe depression of the moment. The present industrial conditions necessarily meant hard conditions and scarcity of labour

MR. FRANCIS W. ROWE.

Mr. Francis W. Rowe, B.Sc., is Chief Metallurgist with Messrs. David Brown & Sons, Limited, the gearing specialists, of Huddersfield. He was educated at Manchester Grammar School and Manchester University, and has also done research work at Sheffield University. He served a special metallurgical apprenticeship with Messrs. Metropolitan Vickers, and was afterwards for some years in the laboratory of the Partington Steel & Iron Company. He then joined Messrs. J. Hopkinson & Company, the valve makers, as assistant to the Chief Metallurgist, and was later appointed Chief Metallurgist to Messrs. Mather & Platt, Limited, of Manchester, with whom he was for many years. He resigned this position to become Head of the Research Department with his present firm some eighteen months ago. Mr. Rowe is the author of a number of papers presented before technical bodies, chiefly the Institute of Metals and the Institution of British Foundrymen, and has been awarded two diplomas by the latter body for papers presented before Branch meetings. He is a member of most of the societies interested in metallurgy both in this country and abroad.

for the foundrymen. Moreover, their industry was not a protected one. It must bear the brunt of foreign competition. There seemed to him to be only one way of meeting that, and that was to get right down to the job. If they put brains into their methods and organisation, and if their operatives would have sufficient flexibility to meet changing conditions, then he was quite convinced that nobody would beat them back. Great Britain had the best chance of any country. It had a good

reputation, and he was glad to think it still had the first call on the world's markets.

MR. JOHN CAMERON, in acknowledging the sentiment, said he had to thank Mr. James Weir for taking his brother's place at this time. Lord Weir had been good enough to send him a nice letter explaining his absence, but his place had been filled to some extent by the presence of Lady Weir. It was with somewhat mixed feelings that he stood before them that evening. Frankly he had never been so proud of any position he held as of the fact that he was presenting the President of the Institute of British Foundrymen. Although he felt proud of the Institute and himself that night his pride was intermixed with the regret they all felt in the loss of Robert Buchanan—the first President, and a magnificent Scotsman. He made himself a friend to everyone in the industry. Although the deceased was the first President of the Institute his interest in its welfare was keen to the very end. The memory of those who had gone before encouraged the others to live up to their example. They would strive to see that under their management the Institute would not lose the honour and dignity secured for it by those who had gone before. Touching upon the fact that the work of the Institute was latterly taking on a more international character, the President alluded to the exchange of papers between France and America. Next year the Institute was to be invited to take part in one of the international congresses which on this occasion would be held in America. Later on this year one on a smaller scale was to be held in Belgium. Reference had already been made to the fact that on the following day the members of the Institute were going to be the guests of many good friends in Falkirk. In Falkirk they would have an opportunity of seeing castings made that went to every corner of the globe—civilised and uncivilised. Proceeding, the President went on to say that the work of the Institute was a splendid one. It had nothing to do with the mundane matters of making money or bargaining with labour. It had on the other hand a great deal to do with interesting the men and even the apprentices. It set out with the ideal of making apprentices and men take a greater pride in their craft and in generally equipping them for the highest position which the art of the foundrymen offered. There were many connected with the ironfounding industry—he was speaking more particularly of employers now—who had not time to come to the Branch meetings and take part in the discussions. He appealed to such employers, however, to give encouragement to the men to go out to the meetings. From his own experience he could testify to the good he had derived from taking part in the work of the Institute, and if employees were afforded facilities and encouragement by the employers so as to identify themselves with the Institute it would lead in the long run to the development and advancement of the industry.

COLONEL J. A. ROXBURGH, president of the Glasgow Chamber of Commerce, proposed the toast of "Scientific and Technical Institutions," and this he coupled with the name of Professor Mellanby, D.Sc., the president of the Glasgow Section of the Institution of Mechanical Engineers. Colonel Roxburgh said he took the view that the time was past when anyone could carry on a business or an industry in a water-tight compartment. In the old days each man was a law unto himself. He had been struck with the public-spiritedness of the foundrymen. Most of them, like himself and others present, were in business to make money out of it but the foundrymen seemed to be in business to benefit their neighbours and the world in general. People who were in possession of these sentiments and lofty ideals certainly required no words of his to commend them. His notion was that at the present time the scientific and technical institutes required to get right down to the root of things. They required to get down to facts and first costs. He had the belief also that in the processes which they operated or controlled they ought to strike out in order to see in what direction they could improve their work. The scientific and technical institutions were useful in the way of investigation, and in the direction of showing people who were interested how to improve processes and methods. They served a useful part in training the young to take their rightful places in the industries with which they were associated. It had always seemed to him that they could not bestow too much praise on the various scientific and technical institutes for the work they were doing in the country. Many of those present must know from practical experience that these institutes were doing excellent work and that they were rendering useful service to the country.

PROFESSOR MELLANBY, with whose name the toast was coupled, referred to the benefit which had accrued to craftsmen in Glasgow by the fact that there had recently been combined meetings of the Glasgow Branch of the Institute of British Foundrymen and the Glasgow Section of the Institution of Mechanical Engineers. These meetings had been unique in that representations were present from the engineering shops in the shipyards, and as the outcome of the discussions they had learned a great deal as to the problems associated with the treatment of Diesel engines, for example. He was grateful to Colonel Roxburgh for the kindly references he made to the scientific and technical institutions, and he felt glad to learn that there was a general appreciation of the admirable work they were doing in the country.

"The Scottish Branch of the Institute of British Foundrymen" was afterwards proposed in appropriate terms by Provost Wm. Muirhead, of Falkirk. Mr. James Affleck, B.Sc., the President of the Scottish Branch, made a suitable acknowledgment.

Amongst those present were:—Mr. John Cameron (who presided); Bailie Angus McDougall; Mr. James Weir, of Cathcart; Sir Archibald M. Innes-Shaw, Glasgow; Mr. H. Thomson Clark, manager of the "Glasgow Herald"; Rev. Dr. McLean Watt, minister of Glasgow Cathedral; Mr. R. O. Patterson, retiring past-president; Professor A. L. Mellanby, D.Sc., President of the Glasgow Section of the Institution of Mechanical Engineers; Colonel Roxburgh, President of the Glasgow Chamber of Commerce; Mr. J. T. Forgie, Hamilton (Messrs. Wm. Baird & Company, Limited, coalmasters); Mr. J. M. Mowat, secretary of Messrs. Wm. Jack & Company; Mr. James Affleck, President of the Scottish Branch; Provost Muirhead, Falkirk; Mr. A. Logan, of the Central Ironmoulders' Association; Mr. John King, chairman of the National Light Castings Association. The croupiers were:—Mr. Wm. Bell; Mr. J. Longden; Mr. Oliver Stubbs, past-president; Mr. V. C. Faulkner, London, senior vice-president; Mr. F. J. Cook, past-president; Mr. Tom Bell; Mr. G. A. Dudley. The musical director was Mr. J. C. Dorsie, while the stewards in connection with the banquet were Messrs. H. Winterton and J. Longden. A feature of the menu was the prominence given to "the haggis." The fact that the "great chieftain of the pudden race" was ushered in with full musical honours—typically highland at that—occasioned great amusement amongst the English visitors.

List of Members attending the Conference.

J. Affleck (President, Scottish Branch), Major J. Wathey (Birmingham), J. H. Andrew (Glasgow), J. Arnott (Glasgow), James G. Arnott (Glasgow).

T. Bell (Barrhead), W. Bell (Airdrie), E. Bean (Hull), A. S. Beech (London), A. Brailsford (Newcastle), W. S. Betham (South Shields), J. Bartram (London), A. H. Bacon (Glasgow), W. H. Bound (Middlesbrough), A. Bruce (Edinburgh), John Bell (Glasgow, Convention Secretary).

J. Cameron (Kirkintilloch, President); G. F. Cockram (Ipswich), F. J. Cook (Past-President, Birmingham), G. C. Castle (Liverpool), A. Campion (Glasgow), A. M. Cleverley (Falkirk), F. J. Cree (Peterborough).

J. Durrans (Sheffield), D. Dalrymple (West Bromwich), V. Delport (London), J. C. Dorsie (Kirkintilloch), W. B. Davidson (Arbroath), J. W. Donaldson (Greenock), G. A. Dudley

(Wishaw), J. Dickson (Glasgow), E. Dickinson (Sheffield).

G. Edginton (Chesterfield), James English (Oldham), Wm. Edgar (Kirkintilloch).

V. C. Faulkner (Vice-President, London), J. E. Fletcher (Consultant, B.C.I.R.A., Dudley), Thomas Ferlie (Auchtermuchty), J. Y. Frame (Hull), J. W. Freer (Wallsend), A. R. Fraser (Bearsden), R. W. Fowler (Glasgow), T. E. Fowler (London), B. Fender (Newcastle).

P. Gillespie (Bonnybridge), A. F. Gibbs (London), Colin Gristy (Monkseaton), J. E. Gibson (Falkirk).

F. H. Hurren (Coventry), A. Harley (Coventry), R. L. Hunter (Polmont), H. Hyman (Glasgow), R. R. Hargreaves (Manchester), R. E. Hog (Hull), J. Hogg (Burnley), R. Horn (Falkirk), M. B. Herbst (Gateshead), G. B. Henderson (Southampton), J. E. Hurst (Kilmarnock), Wm. Heywood (Manchester), P. Hetherington (Glasgow), C. Heggie (Birmingham), W. A. Homer (Walsall), Miss Hollinworth (Acting Secretary, London).

J. Irvine (Paisley), A. W. James (Ipswich), Commander Jackson (Sheffield), J. B. Johnson (Tipton), David King (Glasgow), Wm. Kerr (Glasgow), Jas. Kennedy (Cambuslang).

J. London (Clydebank), E. Longden (Birmingham), G. Lillie (Rowlands Gill), J. Lee (Wallsend), R. Lumley (Bonnybridge), A. Logan (Newcastle), J. Laud (Glasgow).

T. W. Markland (Bolton), T. Macfarlane (Horsehay), T. Makemson (Manchester), J. Macfarlane (Glasgow), A. F. Mearns (Glasgow), W. G. Marshall (Larkhill), F. E. McGrah (Wolverhampton), J. S. Morehead (Glasgow), H. J. Maybury (London), J. McNab (Falkirk), A. McGovan (Glasgow), J. McEachan (Kirkintilloch), Wm. McCulloch (Glasgow), J. McArthur (Motherwell), R. Macnab (Paisley), A. D. MacKenzie (Edinburgh), J. J. McCall (Glasgow), J. McIntyre (Kirkintilloch), J. Murdock (Glasgow), J. B. McTurk (Falkirk), G. Mackay (Paisley).

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H. J. Young (Wallsend), James Young (Paisley), R. Yates (Accrington), R. Yeoman (Stockport).

Conference Asides.

The early-morning trials of the inter-branch carpet-sweeping championships showed indications that final honours are likely to go to Birmingham, as their performance and methods were both adaptable and constructive.

* * *

London visitors to Glasgow discovered a means of getting sunburnt other than by exposure to sun and wind.

* * *

It was finally established that the English visitor with the Yankee fittings was not Mr. Harold Lloyd.

* * *

A sample of lime received by an Anglo-American-French delegate during the trip down the Clyde showed a very low CaO content.

* * *

A "young" delegate from Tyneside has taken home with him samples of cheese and Scotch table ware for analysis.

* * *

As the haggis was such a success at Glasgow, several fine young specimens have been caught, sent to England, and will be fattened up ready for killing for next year's conference.

* * *

We dissociate ourselves from the Scotch method of appraising the value of Presidents by girth.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

International Test Bar Situation.

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—We have been very surprised to see in your issue of June 4, in "Notes from France," the following lines:—

"The report of the A.T.F. Commission on the testing of cast iron, after reviewing the work done by the A.F.A. and the I.B.F., states that, so far as the test bar representing the casting and not merely the metal in the ladle, they are in agreement with the British. The French, together with the Belgian and Czecho-Slovakians, are working on the Fremont machines."

It could be understood from these lines that the report of the A.T.F. Commission mentions that the American Foundrymen's Association is not in agreement with the French point of view, that a bar cast separately cannot represent a casting. So far, we are convinced that this is not the opinion of the A.F.A. Committee, but we are certain that we never mentioned that such was the case.

We reproduce below the translation of the terms of the report of the commission of methods of testing cast iron to the General Council of the Association Technique de Fonderie:—

"We must mention that it has been decided at this meeting (Milwaukee Conference) that the point of view of the A.F.A. is the following: the bars cast separately may be used to qualify the metal but not the castings, as per the opinion supported up to now by the French committee. It is consequently a success for this committee.

"To qualify the metal they seem to be decided in America to select a round bar of 1.2 in. by 18 in. between supports. We must mention here that I.B.F. prefers three bars of different dimensions which are intended not only to qualify the metal but also the casting. Here the British Association differs from our point of view."

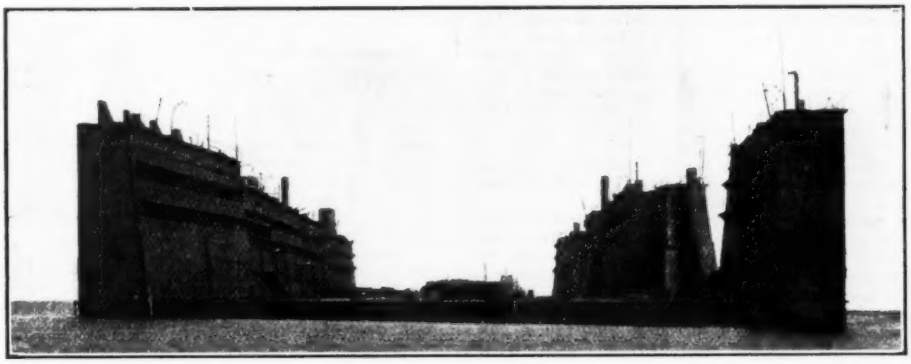
It is certainly by a misunderstanding that you have printed the above lines, as it means exactly the contrary of what we said.—Yours, etc.,

E. RONCERAY,
The Secretary of the French Committee on Methods of Testing Cast Iron.

Scrap Supplies for the Foundry.

While at the moment most descriptions of ferrous scrap are a drug on the market, and prices have fallen as rapidly, or even more so, than those of the finished product, there always has been, and always will be, a good market for shipyard scrap. Naturally, the prices of this material have been affected by the general slump, and this decline, combined with high wages and the cost of tools and raw materials, have been responsible for the state of inactivity and loss associated with the shipbreaking industry for many months. It is, therefore, encouraging to find a few firms able to tide over the serious difficulties that are overshadowing the shipbreaking industry at the moment, as it is obvious that the supplies of scrap in this country are exceedingly small, and would be exhausted by a couple of weeks' ordinary activity in the iron and steel industries.

One of the most enterprising firms in the industry is Cox & Danks, Limited, of 168, Regent Street, London, W.1, who are actively engaged in raising the sunken German fleet at Scapa Flow, in addition to operating a shipbreaking yard at Queenborough, Kent, and warehouses and stockyards at Sheffield, Cradley Heath, Old Hill, Manchester, and Birmingham. In addition to stocks of special steels peculiar to the Sheffield trade, all these warehouses carry large stocks of iron and steel products and scrap of uniform quality and size.



THE EX-GERMAN FLOATING DOCK ACQUIRED BY COX & DANKS, LIMITED.

The firm announce the successful raising of the thirteenth German destroyer, the S32, which, in consequence of the heavy weather experienced in the North of Scotland lately, has taken nine days to complete, as against only four days for the whole operation of uprighting, lifting, and towing into the firm's base at Mill Bay (a distance of about four miles) in the case of the S56, on June 5.

Cox & Danks, Limited, have been successful in purchasing from the Admiralty the ex-German floating dock No. 23, which has been lying for some time at Chatham. This is one of the largest floating docks in the world, and its lifting capacity is 40,000 tons. Composed of six separate sections, it has an overall length of about 703 ft., being 194 ft. broad, and is a sister dock to the one which set out during the last few days, towed by six tugs, for Malta. The company state that this dock has been purchased by them for breaking up at their Queenborough shipbreaking depôt on the Medway, Kent, where they have just completed the demolition of the two Dreadnoughts, *Erin* and *Orion* (which were 25,000-ton capital ships), under the terms of the Washington Treaty. The firm propose to adapt one section of this floating dock at Queenborough, and tow it the 700 miles up to Scapa, so that it may take part in the salvage of the German fleet. This section of the dock will probably be found to play an important part in connecton with the raising of the larger sunken German ships. The breaking up of the other sections of the dock at Queenborough will provide employment for a large number of men for the remainder of this year.

Cast-iron Houses.

Wortley, Sheffield, Rural Council Experiment.

The Wortley (Sheffield) Rural Council have decided to erect six cast-iron houses on their Mortomley housing estate, and have placed the order with Newton, Chambers & Company, Limited, of the Thorncliffe Iron Works.

These houses will be the first cast-iron houses erected under any Council, and will, possibly, give a lead to an industry which may become most popular throughout the country. Newton, Chambers & Company, Limited, are the sole manufacturers of the cast-iron houses, which have the full approval of the Ministry of Health, whose Inspectors have visited two houses specially erected as examples by the company.

The houses have an excellent appearance, and it is claimed that they afford better interior comfort than brick and stone houses. The estimated time for erection is four days per house.

Mr. T. V. Miles, general manager of the company's iron works, states that the company are most anxious to relieve the acute housing shortage, and the coal and iron trades, which are so depressed, will, if the cast-iron houses are adopted, be considerably relieved.

Foundry Extension at Falkirk.

At Falkirk Dean of Guild Court, on June 18, application was made by the Burnbank Foundry Company, Limited, Falkirk, for a warrant to extend their moulding shop, alter and renew two of the present roofs, and erect a new stair. This extension is one of several being made at present in foundries in Falkirk. The application was granted.

Foundry Query.

Normal Foundry Losses.

SIR,—We should be glad if you would inform us what is the recognised percentage of waste in the melting of iron in a jobbing foundry. We require this information to enable us to estimate the amount of scrap iron which was in this foundry when we took it some months ago, the weight of which not being known. We have the weight of castings made and the weight of pig and scrap purchased, and the difference plus loss in melting should produce the information required.—R. & P.

Institute of British Foundrymen (LANCASHIRE BRANCH—JUNIOR SECTION).—Sir W. G. Armstrong, Whitworth & Company, Limited, have invited the members of the Junior Section of the Lancashire Branch to visit their works at Openshaw, Manchester, on Saturday, June 27. The members assemble at the head office, Whitworth Street, Openshaw, at 3 p.m. The Stanton Ironworks Company, Limited, of Stanton, near Nottingham, have invited the members to visit their works on Saturday, September 12.

IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—Conditions in the Cleveland iron trade are without signs of early improvement, and, so far as actual business is concerned, the outlook must be pronounced as most unsatisfactory from every point of view. Consequently foundry consumers are now only buying small quantities to cover day-to-day requirements, and in view of the fact that in the majority of cases they are having to take orders at extremely narrow margins, there is no other policy open to them. The export position is also discouraging. The settlement of the strike in Denmark has released deliveries which have been held up for a very long time, but as a set-off to that there is the collapse both of francs and lira, which effectively stifles inquiry from abroad. Moreover, it is intensifying French and Belgian competition in neutral markets. As regards values, No. 3 G.M.B. has developed further weakness, and the price to-day is about 73s. per ton, a little business being put through at that figure. No. 1 is quoted at about 77s., No. 4 foundry 72s., and No. 4 forge 71s. 6d. per ton.

The Tees-side hematite market continues practically unchanged. There is, however, a fairly steady inland business, but it is on a small scale, and only prompt lots are changing hands. Export trade shows but little movement, sales being very slow. Values are again weaker, East Coast mixed numbers being down to 78s. per ton, with No. 1 at 6d. per ton premium. In the North-West area, prices are generally unchanged, Bessemer mixed numbers being 87s. 6d. c.i.f. Welsh ports, 89s. 6d. per ton delivered at Glasgow, 96s. per ton delivered at Sheffield, and 97s. 6d. per ton delivered at Birmingham.

LANCASHIRE.—With the general demand for castings in this locality still much below average, the market for foundry pig is correspondingly quiet, and prices again show a weaker tendency. The ruling quotation for Derbyshire No. 3 foundry quality is now down to 80s. delivered Manchester, but reports are current that even this price can be shaded for substantial parcels. For Northamptonshire iron the nominal price at the furnaces is still 67s. 6d., but when it has to be sold to South Lancashire, less has to be taken, although it competes very well at that price for the Midland markets.

THE MIDLANDS.—At Birmingham last week buying on foundrymen's account was only on a restricted scale, local consumers having to cut their prices for castings very fine indeed to make business possible, and are consequently out to get every penny concession they can from the furnaces. In view of the price weakness they are disposed to limit their purchases to small quantities, and there is practically no forward buying at the moment. Ruling prices are as follow:—Derbyshire No. 3 foundry, 72s. to 73s. 6d.; Staffordshire No. 3 foundry, 72s. 6d.; Northants No. 3 foundry, 66s. to 67s. 6d.

SCOTLAND.—The near approach of the annual midsummer holidays in the North has accentuated the dullness in the Scottish pig-iron industry, with business now reduced to almost negligible proportions. Prices have consequently reflected further weakness, No. 3 foundry now quoting down to 83s. at furnaces, with a very indifferent demand at that comparatively low figure.

Finished iron.

Business in all sections of the manufacturing departments continues unsatisfactory, with perhaps an exception in the case of marked bar makers, who are recently reported to have secured additional specifications for this class of material. There is still keen competition for orders for crown quality iron, and some cutting below £12 7s. 6d., the current quotation, is reported. It is, of course, quite impossible for the local mills to offer inducements for business in the nut and bolt section, as they are between £4 and £5 per ton higher in price than the Belgian No. 3 iron, which quality is quite suitable for the Darlaston trade, and is now obtainable at a shade under £7 per ton, delivered, against the Staffordshire price of £11 7s. 6d. per ton. It will be seen at once that of necessity the bulk of the business for the cheap iron for the bolt and fencing trade must go abroad, and recently there has been a fair amount of business going in this direction.

Steel.

The outlook in the steel industry at the moment is somewhat obscure, while current business is distinctly quiet. At Sheffield the inquiry for acid steel billets has fallen to a low average, and the revision of basic billet prices has, so far, had little effect on demand. In this district less than a quarter of the basic furnaces are in operation, and numerous acid plants are now out of action indefinitely. Makers of crucible steel report dwindling orders. Tool steel is fairly good, with a distinct revival in the tool branches. In Europe makers of ferro-manganese are holding their position well, and follow British prices very closely. British ferro-manganese is on offer in the North of France at £17 10s. delivered, and £17 5s. delivered elsewhere in that country. In the tinplate market primes have been done down to 19s. 7½d., basis I.C., f.o.b. works port. Generally, however, business is round 19s. 9d. to 20s. 3d. basis. It is stated that efforts are being made to resuscitate the stabilisation of prices scheme.

Scrap.

There is no improvement to report in the markets for scrap metal, which remain completely stagnant in all departments. In Lancashire at present it is possible to buy good broken machinery cast scrap at 75s. per ton delivered, with only a limited business passing at that figure. In Scotland the foundries are buying very little machinery cast-iron scrap, and the price they are paying is only around 82s. 6d. per ton. Ordinary cast-iron scrap to the same specification can be had very freely at 75s. per ton, and for steelworks material in furnace sizes 72s. 6d. per ton. Light cast iron and firebars are still unsaleable, but the nominal price is around 60s. per ton. The above prices are all per ton delivered f.o.t. consumers' works.

Metals.

Copper.—Movements in the standard market during the current week have maintained a steady tendency, with a slight improvement in values. As previously reported, the market has shown very little improvement, or the reverse, from week to week. Prices have not moved much, and in the absence of speculative activity, changes have been exceedingly moderate, rarely registering more than 5s. either way on the day. Current quotations:—*Cash*: Thursday, £60 7s. 6d.; Friday, £60 10s.; Monday, £60; Tuesday, £59 17s. 6d.; Wednesday, £60.

Three Months: Thursday, £61 7s. 6d.; Friday, £61 7s. 6d.; Monday, £61; Tuesday, £60 17s. 6d.; Wednesday, £60 17s. 6d.

Tin.—Following some profit-making by the speculative element, tin values recently developed a slight weakness, but with business on the whole rather active. The monthly figures were not favourable to the bulls, as they showed a large increase, but some good American buying has helped the position, and prices have generally been maintained. Taking the world's visible supply at about 20,000 tons all told, there has been since the beginning of the year a considerable reduction in the quantities of metallic tin available for market purposes. Current quotations:—*Cash*: Thursday, £253; Friday, £252 15s.; Monday, £251 17s. 6d.; Tuesday, £252 5s.; Wednesday, £252 15s.

Three Months: Thursday, £254 15s.; Friday, £254 7s. 6d.; Monday, £253 17s. 6d.; Tuesday, £254 7s. 6d.; Wednesday, £254 12s. 6d.

Spelter.—The market for this metal continues inactive, and the undertone, if anything, has been somewhat easier, due to liquidation and heavy arrivals. Reports from America are not so confident, and there has apparently been a slowing-down in the demand, not only for home use, but also on export account. Trade users in this country are not inclined to buy at present prices; thus it does not follow that present level of prices can be maintained for any length of time. Current quotations:—*Ordinary*: Thursday, £34 2s. 6d.; Friday, £34; Monday, £33 18s. 9d.; Tuesday, £34 5s.; Wednesday, £34 2s. 6d.

Lead.—The high values recently registered for soft foreign pig are well maintained, and, although arrivals during the last two or three months have been on a heavy scale, all supplies seem to be easily absorbed. Reports received from America indicate that the markets there are very firm, and there is no doubt that the bullish sentiment that prevails on the other side of the Atlantic has some influence on the position here. Current quotations:—*Soft foreign (prompt)*: Thursday, £33 12s. 6d.; Friday, £33 5s.; Monday, £33; Tuesday, £33 7s. 6d.; Wednesday, £33 10s.

MR. J. HILL, general secretary of the Boilermakers' Society, states in his monthly report that 25,033 of the society's members are out of work.

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Index to Advertisers, p. 15. Situations, etc., p. 20. B

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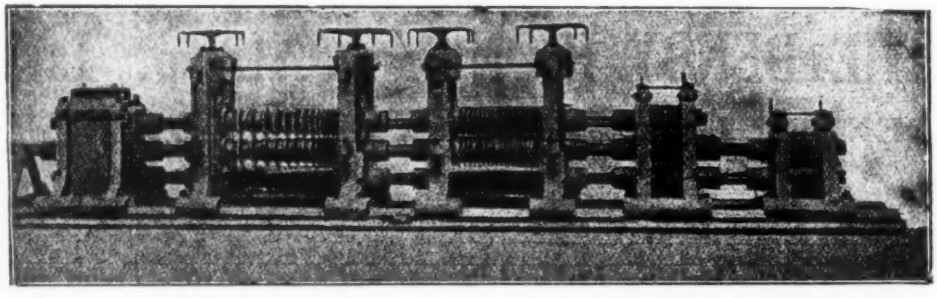

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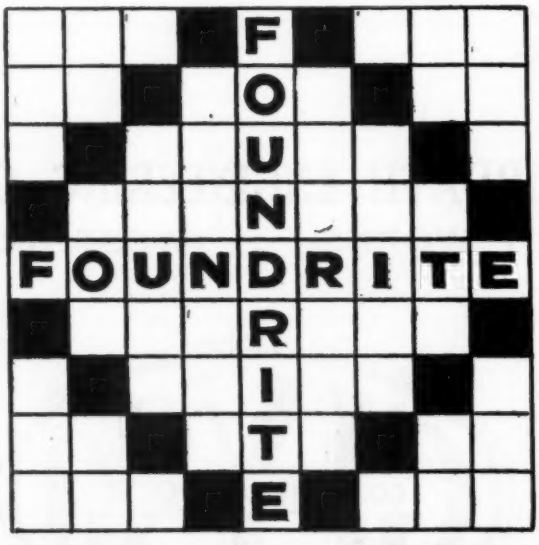

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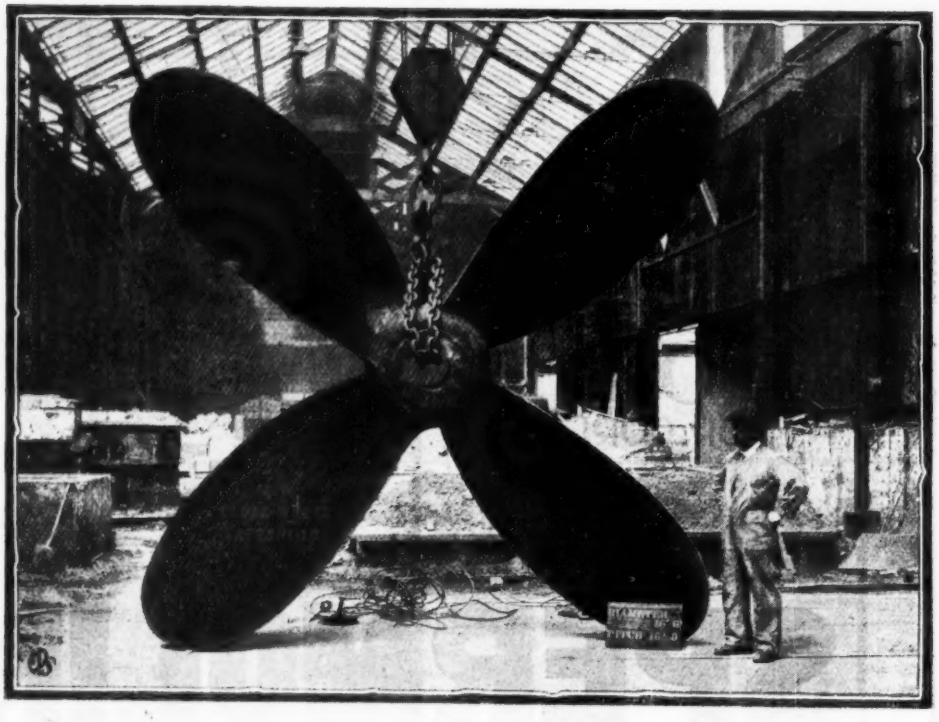

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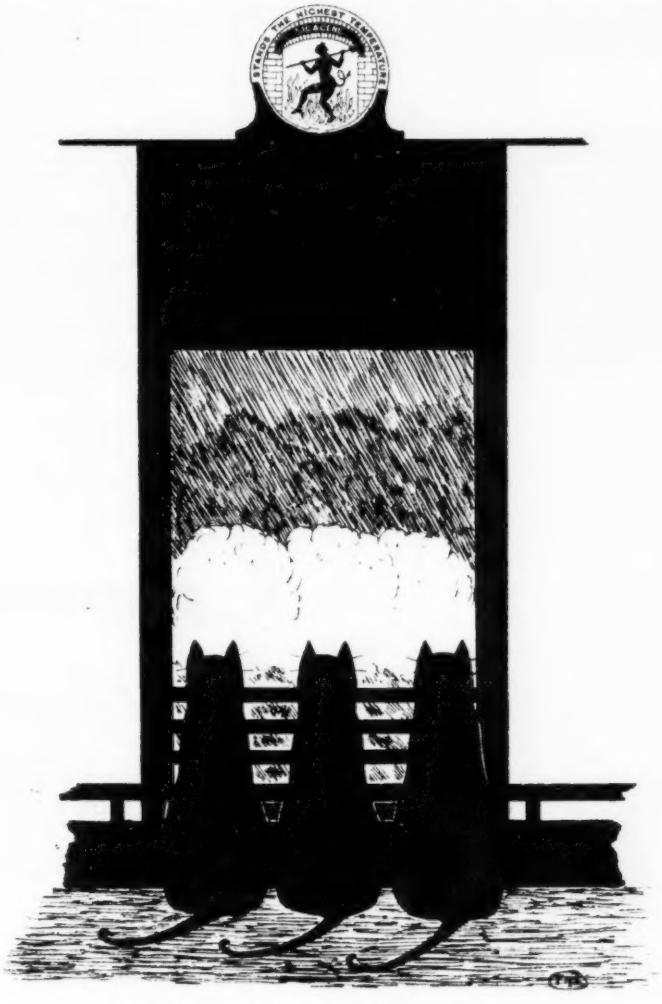

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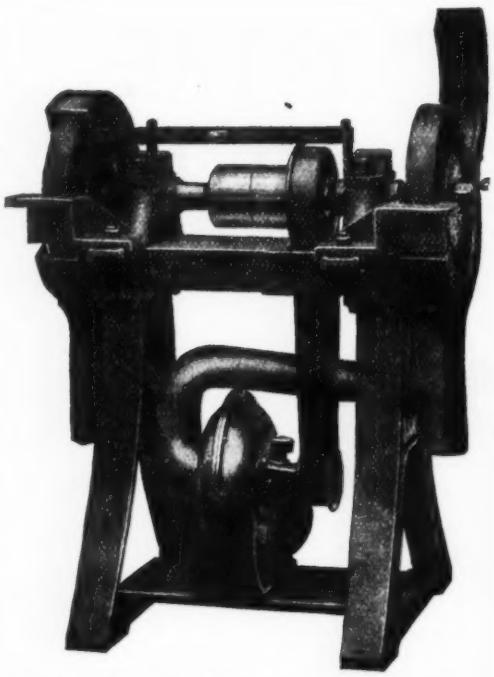

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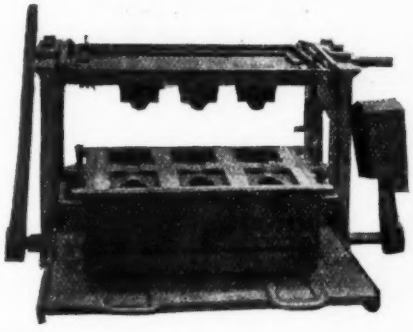

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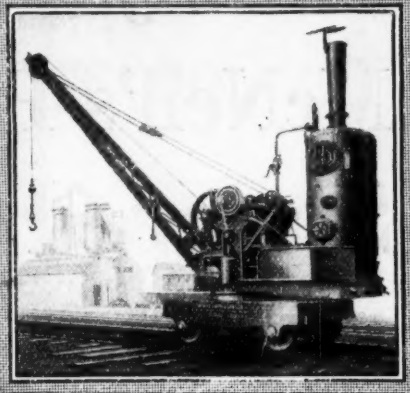

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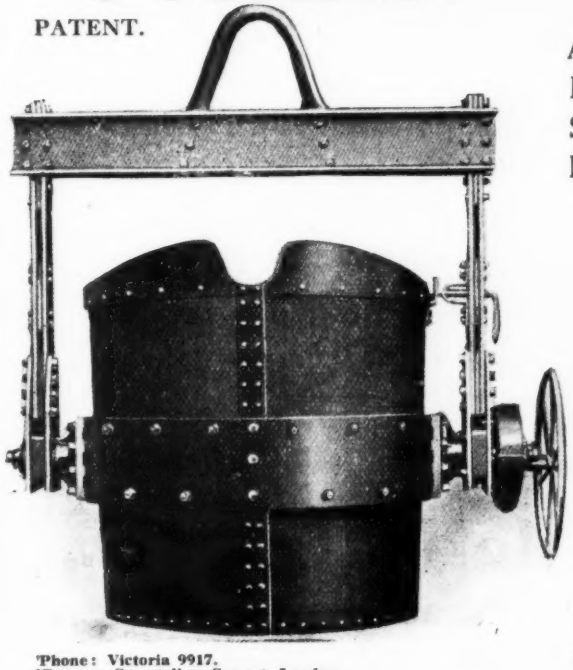

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Armstrong-Whitworth, Sir W. G. & Co., Ltd.	8
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Coltness Iron Co., Ltd.	16
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Consett Iron Co., Ltd.	—
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Cumming, Wm., & Co., Ltd.	—
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Delf, Jones & Co.	16
Denbigh Engineering Co., Ltd., The	22
Denby Iron & Coal Co., Ltd.	3
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Electric Furnace Co., Ltd.	—
Eleringer, Simon	—
Evans, J., & Co.	—
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Fleming, J. & R.	20
Fordath Engineering Co., Ltd.	5
Foster Bros., Ltd.	—
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Furmston & Lawlor	26
Gadd, Thos.	—
General Refractories Co., Ltd.	13
Gibbons Bros., Ltd.	24
Gossell & Son, Ltd.	—
Gray, Thos. E., & Co., Ltd.	9
Green, George, & Co.	—
Hall, J., & Co. (Stourbridge), Ltd.	28
Hammond, Alex.	20
Harper, Wm., Son & Co.	—
Harvey-Siemens Furnaces, Ltd.	2
Hawkins, W. T., & Co.	—
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Hinckley, J., & Son	—
Hingley, N., & Sons, Ltd.	4
Hunt, F. L., & Co.	29
Incandescent Heat Co., Ltd.	—
International Foundry Equipment Co.	14
Jacks, William, & Co.	19
James, Wm.	6
Jones, Geo., Ltd.	—
Jordans, Ltd.	
Keighley Laboratories Ltd.	—
Keith, James, & Blackman Co., Ltd.	—
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Lilleshall Co., Ltd.	23
Longden, G. & Son, Ltd.	14
Lowood, J., Grayson & Co., Ltd.	—
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McNeil, Chas.	12
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Roberts, Wm., & Son	—
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Salter, T. E. Ltd.	10
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Shropshire Iron Co., Ltd.	27
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Smart, H. & H. E.	26
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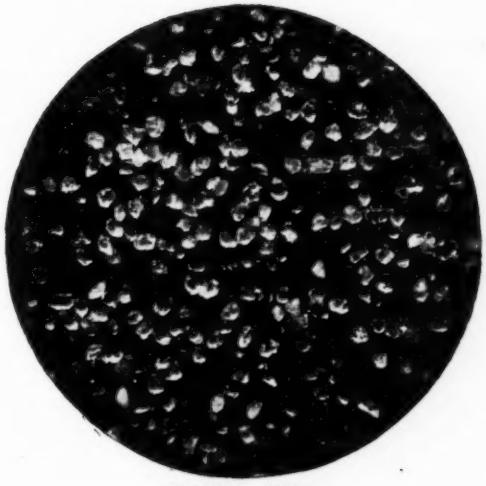

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Lincs. forge ..	—
,, fdry. No 3 ..	79/-
E.C. hematite ..	88/6
W.C. hematite ..	96/-
Lincs. (at furnaces)— Forge No. 4 ..	—
Foundry No. 3 ..	73/-
Basic	72/-
Lancashire (d/d eq. Man.)— Derby forge ..	79/3
,, fdry. No. 3 ..	80/-
Northants foundry No. 3 ..	80/3 to 80/6
Dalzell, No. 3 ..	111/6
Summerlee, No. 3 ..	100/6
Glengarnock, No. 3	100/6
Gartsherrie, No. 3 ..	100/6
Monkland, No. 3 ..	100/6
Coltness, No. 3 ..	100/6
Shotts, No. 3 ..	100/6

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.)	11 12 6 to 13	0 0
Angles	12	7 6
Tees to 3 united ins	13	2 6
Nut and bolt	11	15 0
Hoops	14 0 0 to 15	0 0
Marked bars (Staffs.) f.o.t. ..	14	10 0
Gas strip ..	13	0 0
Bolts and nuts, ¾ in. × 4 in. ..	16	15 0
Steel— Ship plates	8 15 0 to 9	5 0
Boiler plts.	£12 10 to 13	0 0
Chequer plts.	£10 10 to 11	0 0
Angles	£8 5 0 to 8	12 6
Tees	£9 5 0 to 9	12 6
Channels	£7 15 0 to 8	5 0
Joists	£8 5 0 to 8	12 6
Rounds and Squares 3in. to 5½in. ..	9	5 0
Rounds under 3 in. to ¾ in.	9	0 0
Flats, over 5 in. wide and up ..	9	15 0
Flats, 5in. to 1½in.	8	15 0
Rails, heavy ..	8	10 0
Fishplates ..	12	10 0
Hoops (Staffs.)	£11 0 0 to 11	10 0
Black sheets, 24g.	11	15 0
Galv. cor. sheets, 24g.	16	10 0
Galv. fencing wire 8g. plain ..	14	0 0
Billets, soft	6 10 0 to 8	5 0
Billets, hard ..	9	0 0
Sheet bars	6 12 6 to 6	15 0
Tin bars d/d	6 12 6 to 6	15 0

PHOSPHOR BRONZE.

	Per lb	bars
Strip	1	2½
Sheet to w.g. ..	1	3½
Wire	1	3½
Rods	1	2½
Tubes	1	7
Castings	1	2

Delivery 3 cwt. free.

10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S
Phosphor tin (5%) £30 above price of English ingots.

C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled— To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½

Wire round— 3/0 to 10 G. .. 1/6½ to 2/1½ with extras according to gauge.

AMERICAN IRON & STEEL.

At Pittsburgh unless otherwise stated. Dols.

No. 2X foundry, Phila.	21.26
No. 2 foundry, Valley	19.76
No. 2 foundry, Birm.	20.00
Basic	19.76
Bessemer	20.76
Malleable	20.26
Grey forge	19.26
Ferro-mang. 80% d/d	115.00
Bess. rails, h'y, at mill	43.00
O.-h. rails, h'y at mill	43.00
Bess. billets	35.00
O.-h. billets	35.00
O.-h. sheet bars ..	35.00
Wire rods	46.00

Cents.

Iron bars, Phila. ..	2.22
Steel bars	2.00
Tank plates	1.90
Beams, etc.	2.00
Skelp, grooved steel ..	1.90
Skelp, sheared steel ..	1.90
Steel hoops	2.40
Sheets, black, No. 28 ..	3.30
Sheets, galv., No. 28 ..	4.25
Sheets, blue an'l'd, 9 & 10	2.30
Wire nails	2.70
Plain wire	2.50
Barbed wire, galv. ..	3.45
Tinplate, 100 lb. box ..	$5.50

COKE (at ovens).

Welsh foundry ..	37/6
,, furnace	27/6
Durham & North. ,, foundry ..	35/-
,, furnace ..	17/-
Other Districts, foundry	35/-
,, ,, furnace ..	15/9

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. Cokes,	20 × 14, box	19/9
,,	28 × 20, ,,	39/6
,,	20 × 10, ,,	28/9
,,	18¾ × 14, ,,	20/10½
C.W.	20 × 14, ,,	18/3
,,	28 × 20, ,,	36/1½
,,	20 × 10, ,,	25/1½
,,	18¾ × 14, ,,	18/7½

Terneplates 28 × 20, 1/3 per box basis below tinplates.

SWEDISH IRON.

Bars, hammered	£20/0 to £21/0
Rolled Ord.	£16/0/0 to £16/10/0
Nail rods	16 5 0 to £16 15 0
Keg. steel nom.	£33 to £35
Faggot steel nom.	£22 to £25
Blooms, according to quality	£10 to £14
Pig-iron	£6 15 0 to £7 0 0

all f.o.b. Gothenburg.

TUBES.

	Up to and incl. 6 in.
Gas .. 55%	Tube prices are now free.
Water .. 50%	
Steam .. 45%	

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£	s.	d.	
June 18	60	7	6	inc. 2/6
,, 19	60	10	0	,, 2/6
,, 22	60	0	0	dec. 10/-
,, 23	59	17	6	,, 2/6
,, 24	60	0	0	inc. 2/6

Electrolytic Copper.

	£	s.	d.	
June 18	64	0	0	inc. 5/-
,, 19	64	0	0	No change
,, 22	63	12	6	dec. 7/6
,, 23	63	12	6	No change
,, 24	63	12	6	,, ,,

Standard Tin (cash).

	£	s.	d.	
June 18	253	0	0	inc. 10/-
,, 19	252	15	0	dec. 5/-
,, 22	251	17	6	,, 17/6
,, 23	252	5	0	inc. 7/6
,, 24	252	15	0	,, 10/-

Tin (English ingots).

	£	s.	d.	
June 18	253	10	0	inc. 10/-
,, 19	253	0	0	dec. 10/-
,, 22	253	0	0	No change
,, 23	253	5	0	inc. 5/-
,, 24	253	5	0	No change

Zinc Sheets (English).

	£	s.	d.	
June 18	40	0	0	No change
,, 19	40	0	0	,, ,,
,, 22	40	0	0	,, ,,
,, 23	40	0	0	,, ,,
,, 24	40	0	0	,, ,,

Spelter (ordinary).

	£	s.	d.	
June 18	34	2	6	dec. 1/3
,, 19	34	0	0	,, 2/6
,, 22	33	18	9	,, 1/3
,, 23	34	5	0	inc. 6/3
,, 24	34	2	6	dec 2/6

Lead (English).

	£	s.	d.	
June 18	35	0	0	No change
,, 19	34	15	0	dec. 5/-
,, 22	34	10	0	,, 5/-
,, 23	34	15	0	inc. 5/-
,, 24	34	15	0	No change

Exports of Iron Castings in May and the five months, 1925 compared with May and the five months, 1924.

	May, 1924.	May, 1925.	Five months, 1924.	Five months, 1925.	May, 1924.	May, 1925.	Five months, 1924.	Five months, 1925.
BUILDERS' CASTINGS—								
Stoves, Grates, etc., Cisterns, Baths, etc., and cooking and washing boilers:—	Tons.	Tons.	Tons.	Tons.	£	£	£	£
To Argentine Republic	103	177	525	689	3,507	6,047	19,521	23,981
,, British South Africa	316	281	1,199	1,508	11,127	10,505	43,302	54,473
,, ,, East Indies	136	193	525	761	5,416	8,117	24,502	37,074
,, Australia	65	58	328	358	3,447	2,844	18,607	19,312
,, New Zealand	159	199	879	1,162	7,183	9,198	42,530	54,986
,, Other countries	410	722	2,553	3,220	19,522	36,658	126,615	163,429
Total	1,189	1,630	6,009	7,698	50,202	73,369	275,077	353,255
PIPES AND FITTINGS—								
Cast—								
To Argentine Republic	753	1,221	2,331	4,902	9,983	15,793	32,682	64,410
,, British South Africa	996	952	4,338	3,290	11,549	13,329	50,647	45,157
,, ,, India	1,203	922	4,930	4,972	16,875	12,729	72,422	70,729
,, Straits Sttlmnts. & Malay Sts.	238	298	4,534	2,764	3,476	4,816	55,931	32,385
,, Ceylon	151	66	498	566	2,176	798	6,765	7,387
,, Australia	487	337	1,862	1,457	5,219	4,871	27,851	21,811
,, Other Countries	3,267	4,170	14,607	23,375	52,632	65,987	244,564	347,083
Total	7,095	7,966	33,100	41,326	101,910	118,323	490,889	588,962
HOLLOW-WARE—								
Cast, not Enmlled, & Cast, Tinned	560	566	2,639	3,632	22,946	20,380	108,284	117,613
,, Enamelled	95	80	495	445	9,968	8,290	51,087	43,138
CASTINGS, in the rough—								
Iron	117	86	500	508	4,764	3,660	21,612	20,594
Steel	96	49	1,689	212	3,576	2,235	26,224	8,267

WILLIAM JACKS & COMPANY,

WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

18, BENNETTS HILL, BIRMINGHAM.

18, BENNETTS HILL, BIRMINGHAM.
11, OLD HALL STREET, LIVERPOOL.
EXCHANGE BLDGS., PORT TALBOT.
FOWLERS BUILDINGS, BOMBAY.
CLIVE STREET, CALCUTTA.
ANGAPPA NAICK STREET, MADRAS.

REGISTERED TRADE MARK

1, HONG KONG ROAD, SHANGHAI.
OCEAN BUILDING, SINGAPORE.
JAVA STREET, KUALA LUMPUR
5, SHAFFRAZ ROAD, RANGOON.
COX'S BUILDINGS, KARACHI.
P.O. BOX 1580, CAIRO.

PIG IRON

SCOTCH, MIDDLESBRO', HEMATITE, BASIC, SPECIALS, &c.,

NON-FERROUS METALS

COPPER, TIN, LEAD, SPELTER, ANTIMONY, CHROME ORE.

WILLIAM COLVIN & COMPANY,

ROYAL EXCHANGE, MIDDLESBROUGH.

93, HOPE STREET, GLASGOW.

SMALL ADVERTISEMENTS.

Notice.

Small Advertisements in this section of the Journal are accepted at the prepaid rate of 6d. per line, first line in capitals counting two, average 7 words per line. Minimum charge for one insertion 3/-.

SITUATIONS VACANT AND WANTED.

FOREMAN PATTERNMAKER, good organiser, who has made a special study of *modern* machine-moulding, desires change or advisory position between pattern-shop and foundry. — Box 344, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

MOULDER and Core-maker seeks situation; thoroughly experienced in all foundry work; could run small foundry to pay at reduced wage for permanent position; real worker and best attention given to firm's interest; satisfaction assured; distance no object if reliable.—"CONSTANT," Westleigh, Micawber Avenue, Hillingdon, Middlesex.

ADVERTISER, holding Honours and Research degrees in Science, age 32, considerable technical and commercial experience, particularly in Non-Ferrous work, having been Works Manager and Research Metallurgist for several years, seeks position with progressive firm desiring to increase quality and quantity of output.—Apply, Box "C. Q.," Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

IRON FOUNDRY Foreman and Core Shop Chargehand wanted; piecework shop; machine moulding and jobbing work of the highest class; state fully class of work experienced in, sands, etc., age and salary; shop employs about 50 men; London district; young men without experience as supervisors will be considered if they have had good technical and practical experience.—Apply, Box 362, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

BRASS FOUNDRY Foreman, for shop near London employing 10 to 15 men and making first-class castings in small and medium weights for engineers' use; must be able to produce sound castings to War Office and Admiralty specifications.—State very fully experience, practical and technical, age, salary, etc., to Box 364, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

PATENTS.

PATENT YOUR INVENTIONS, Trade-mark your Goods. Advice, Handbook and Cons. free.—B. T. KING, C.I.M.E. (Regd. Pat. Agent, G.B., U.S.A., and Can.), 146A, Queen Victoria Street, E.C.4. 38 years' refs. 'Phone 682 Central.

MACHINERY.

MACHINERY, PLANT, &c.

One pair of MODERN REVERSING MILL ENGINES, by Messrs. Lilleshall Co., Ltd.; direct driven, with pair of cylinders 32 in. diameter x 4 ft. stroke, piston valve type, link motion, on massive girder bed; stop valve, reverse valves, drain cock, etc.

POWERFUL HORIZONTAL DOUBLE GEARED STEAM WINCH, by Clarke, Chapman & Co.; 4 cyls. 11 in. diam. by 12-in. stroke; diam. of drum, 2 ft. 6 in. x 3 ft. face.

Two HORIZONTAL DOUBLE GEARED STEAM WINCHES, by Clarke, Chapman & Co.; 7-in. cyls., 12-in. stroke; drum, 24 in. diam. x 33 in. face.

Seven Nearly New HOISTING AND TRAVERSING PETROL WINCHES, by Hy. Bergerat & Co., for loads up to 10 cwts.; two independent barrels.

POWERFUL MOTOR-DRIVEN WINCH, by Clarke, Chapman & Co.; drum, 3 ft. 6 in. diam., 3 ft. face; driven by Motor, 450 amps., 100 volts, 520 revs.

LANCASHIRE BOILER, 28 ft. x 8 ft. diameter; reinsure 100 lbs. pressure.

LANCASHIRE BOILER, 30 ft. x 7 ft. 6 in. diameter; reinsure 120 lbs. pressure.

25 Open-top RIVETED STEEL CISTERNS, each about 8 ft. long x 8 ft. deep x 8 ft. wide; plates 3/16 in. thick; capacity, 3,200 gallons each.

CATALOGUE OF STOCK MACHINERY, 6,000 Lots. Free on Application. Inspection Invited.

THO W. WARD, LTD.,
ALBION WORKS, SHEFFIELD.

MACHINERY.—*Continued.*

WANTED, Tilting Furnace, 240-300 lbs. capacity, also Tilting Furnace, 500-600 lbs. capacity.—Box 366, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

WANTED, ½-Ton Electric Steel Melting Furnace for A.C. Supply 5,500 volts, 3-phase, 25 cycles; please quote price and state condition and type of furnace.—Box 368, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

WANTED, small Cupola, 2 tons capacity; must be in good condition.—Box 350. Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

OVERHEAD TRAVELLING CRANE (HAND).—One 3-ton S/H Overhead Travelling Crane, 41 ft. 5 in. span, three operations by hand, by Morris; price £60 f.o.r.; span easily shortened.—Further particulars, write Box 370, Offices of THE FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

SAND MIXERS.—New and secondhand. Ask us to quote.—W. BREALEY & COMPANY, LTD., Russell Street, Sheffield.

FIVE-FOOT THWAITES' CUPOLA, used three months, melt about 8 tons per hour, complete with Sirocco blower and new set of lining bricks, height of cupola over all 33 ft., drop bottom and wind belt; just as good as new; £140. Buy from me and save money.—A. HAMMOND, "Boxted," Slough.

A FEW NEW ITEMS—CHEAP TO CLEAR.

NEW

5 ton EVANS geared ladle ..	**£44**
30 cwt. EVANS geared ladle ..	**£24**
Constructional Cupolette & Fan	**£30**
Millett type cokefired corestove	**£16**
250 lb. Allday's Tilting Furnace	**£30**

Buy from me and *Save Money.*

ALEX. HAMMOND —— "BOXTED" —— SLOUGH.

FOR SALE, Two Britannia Jar Ram Moulding Machines; capacity, 10 cwt. at 80 lbs pressure; pattern draw 8 in.; condition as new; price, £50 each.—Box 360, Offices of the FOUNDRY TRADE JOURNAL, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.

MISCELLANEOUS.

PATTERNS.—Inquiries solicited; quotations by return; quick delivery. Castings also supplied, if required, in all metals.—CLEGHORN & CO., Spring Gardens, Worcester.

J & R. FLEMING, LTD
Wholesale Suppliers of
SAFETY GOGGLES
PROTECTION WHICH HELPS BUT DOES NOT HINDER.
A GOOD GOGGLE FOR EVERY JOB.
146 CLERKENWELL ROAD, LONDON, E.C.1

JOLT RAMMING MACHINES.

One No. 0 BRITANNIA with pattern draw -	**£18**
Two No. 1 BRITANNIA with pattern draw, ea.	**£32**
Four TABOR plain shockless 4" jolters, ea.	**£16**
One EVANS shockless 32"×24" *turnover* jolter with 12" pattern draw, fine machine - -	**£90**
One TABOR (14" cyl.) shockless 48"×32" *turnover* jolter with 26" pattern draw - -	**£180**
Two MACDONALD (7" cyl.) turnover jolters to take boxes 40"×24" Ajax type - - ea.	**£120**

All above Machines are in GOOD condition.

BUY FROM ME & ***SAVE MONEY.***

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"BOXTED," SLOUGH.

'Phone: 287 Slough.

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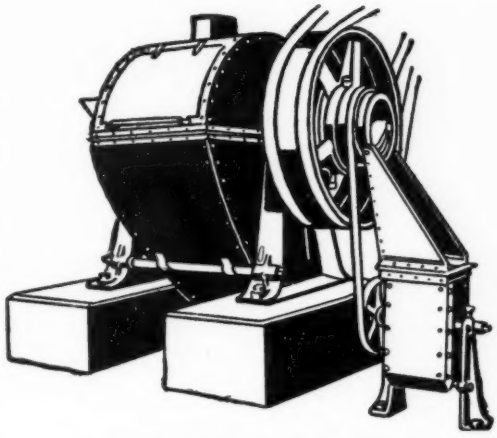


METAL RECOVERY MACHINE WITH MAGNETIC SEPARATOR.

OUR

BRASS RECOVERY MACHINES

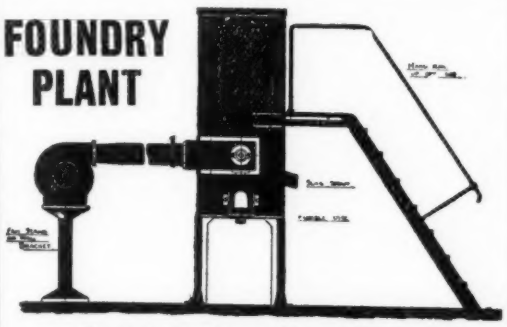
are the last word in the Treatment of Brass Foundry

ASHES AND SKIMMINGS.

If you don't want to lose what your Competitor is saving, you must write to us about it now.

We are at your Service.

FOUNDRY PLANT



E. ROPER & CO. North St., KEIGHLEY.
TELEPHONE: 596. TELEGRAMS: "CLIMAX."

PIFTIN COREBINDER

A FINE DRY POWDER.

Cores made with "PIFTIN" COREBINDER are extremely strong and can be handled freely and kept for weeks without deterioration. Can be cut or filed, removed easily from the casting, and being quite porous, entirely prevent blowholes.

COMPARE WITH OTHERS AND BE GUIDED BY RESULTS.

A 7 lb. sample, sufficient to treat 3 cwts. of sand, sent free on application to

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'Grams: "Russesco," *'Phone: London Wall 7113.*

Something New in Foundry Blackings.

"SLEEKBLACK"

(Trade Mark)

Sleekblack is not **ORDINARY BLACKING,** but is a scientifically prepared blacking embodying a **NEW DISCOVERY,** which improves the sleeking properties and renders ordinary blacking equal to the **BEST** of **NATURAL PLUMBAGO.**

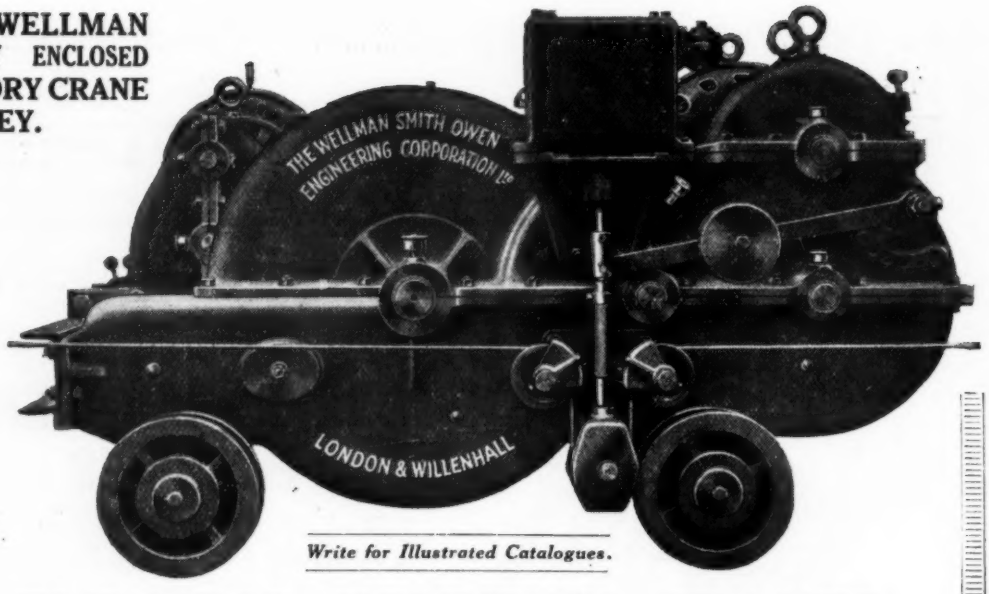
After extensive Experiments and trials these discoveries have been embodied in **SLEEKBLACK.**

For a limited period we are offering trial samples of one hundredweight, carriage paid to any station in Great Britain for 45/-.

Send for quotations for bulk supplies.

THE SLEEKBLACK MANUFACTURING COMPANY,
14, DUKE STREET, KILMARNOCK, SCOTLAND. Phone: 86

THE WELLMAN TOTALLY ENCLOSED FOUNDRY CRANE TROLLEY.



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Our Standard Electric Overhead Travelling Cranes have been designed primarily to meet the requirements of Iron and Steel Foundries. All gears are totally enclosed, ensuring long life under arduous working conditions in the Foundry atmosphere full of dust and grit. All parts are interchangeable. Replacements from stock.

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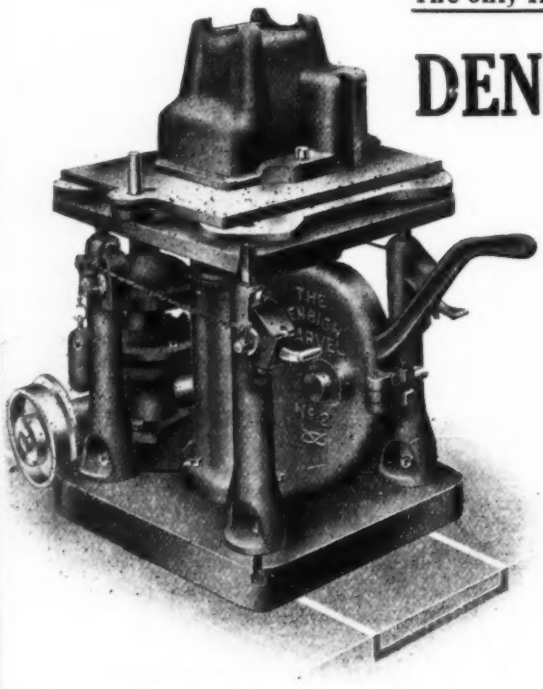
The only Hand Jolt Ramming Machine in the World

THE

DENBIGH "MARVEL"



No Power Required

M/C	Takes Boxparts		Load anyweight	Pattern Draw
No. 0	10 to 12"	wide	to 1½ cwt.	4"
1	10 to 14"	"	" 3 "	and
2	10 to 16"	"	" 5 "	6"
3	12 to 20"	"	" 9 "	8"
4	16 to 30"	"	" 15 "	up to
5	18 to 36"	"	" 20 "	24"

× Any reasonable length.

M/C	Takes Boxes		Load	Pattern Draw
No. 0	12" wide	16" long	1½ cwt.	6"
1	16" "	24" "	3 "	6"
2	18" "	30" "	5 "	6"
3	22" "	36" "	9 "	8"

For further particulars apply:

The DENBIGH ENGINEERING Co., Ltd.

PATENTEES AND MANUFACTURERS,

Horseley Heath, TIPTON.

'Phone: 86. *'Grams: "Denbigh."*

LILLESHALL COMPANY LIMITED.

Cold Blast PIG IRON

Foundry and Forge qualities also qualities highly suitable for Chilled and Grain Roll making; specially strong Castings, &c., &c.

Cylinder Quality a Speciality.

as supplied for high-class Locomotive, Marine and Motor Cylinders.

BRAND "LILLESHALL LODGE C.B."

ALL MINE HOT BLAST PIG IRON Foundry and Forge qualities.

BRAND LILLESHALL H.B.

CYLINDER IRON A SPECIALITY, as supplied for high class Locomotive, Marine & Motor Cylinders.

PRIORS LEE HALL, Near SHIFNAL, SALOP.

Telephone—28 OAKENGATES. Telegrams—LILLESHALL, OAKENGATES.

TELEGRAMS: "IRON BILSTON."

West Midland Refining Co.,

Bilston.

COLD BLAST IRONS

for Chilled Castings.

Chills and analysis guaranteed.

CHARCOAL REFINED HEMATITES

for Malleable Castings.

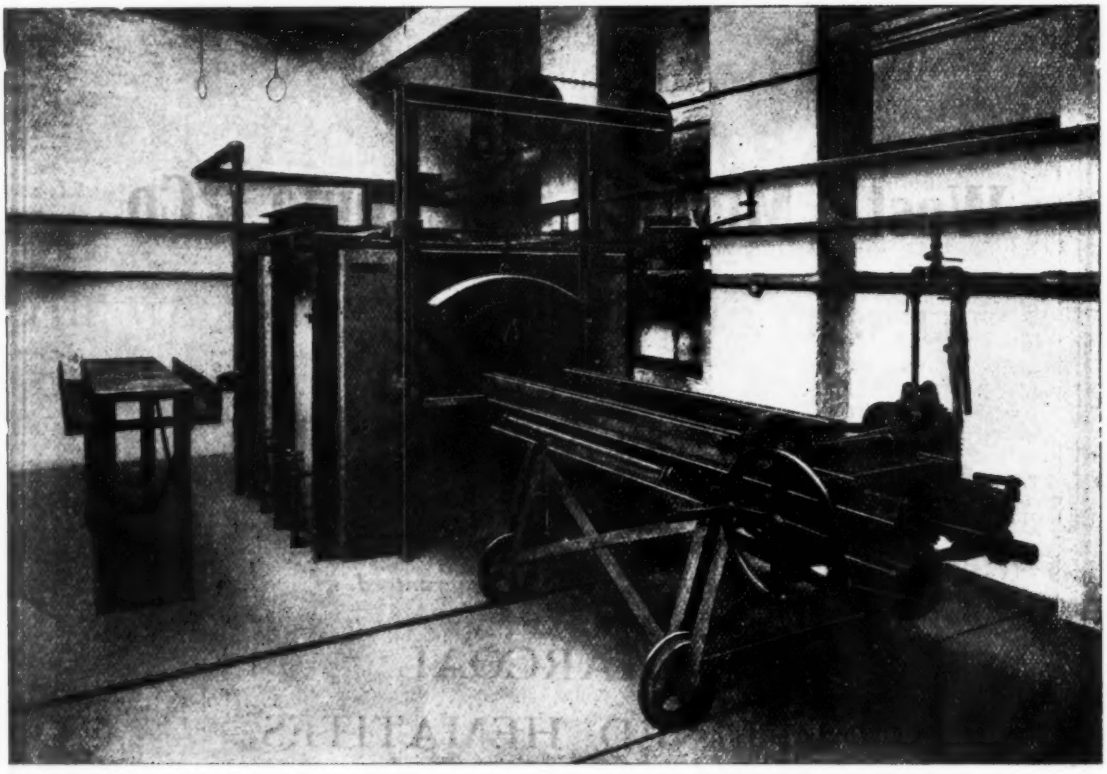
BLACKINGS
PLUMBAGO
COAL DUST
CHAPLETS
NAILS and SPRIGS
CORE GUM
STRAW ROPE
&c., &c.

"Carlton" Patent Blacking

AGENTS FOR
"GLUTRIN"

THOMAS WILKINSON & CO., LTD., MIDDLESBROUGH.

HEAT TREATMENT UNDER IDEAL CONDITIONS



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REGENERATIVE GAS FURNACE AND
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REDUCE ANNEALING & CARBURIZING **COSTS**

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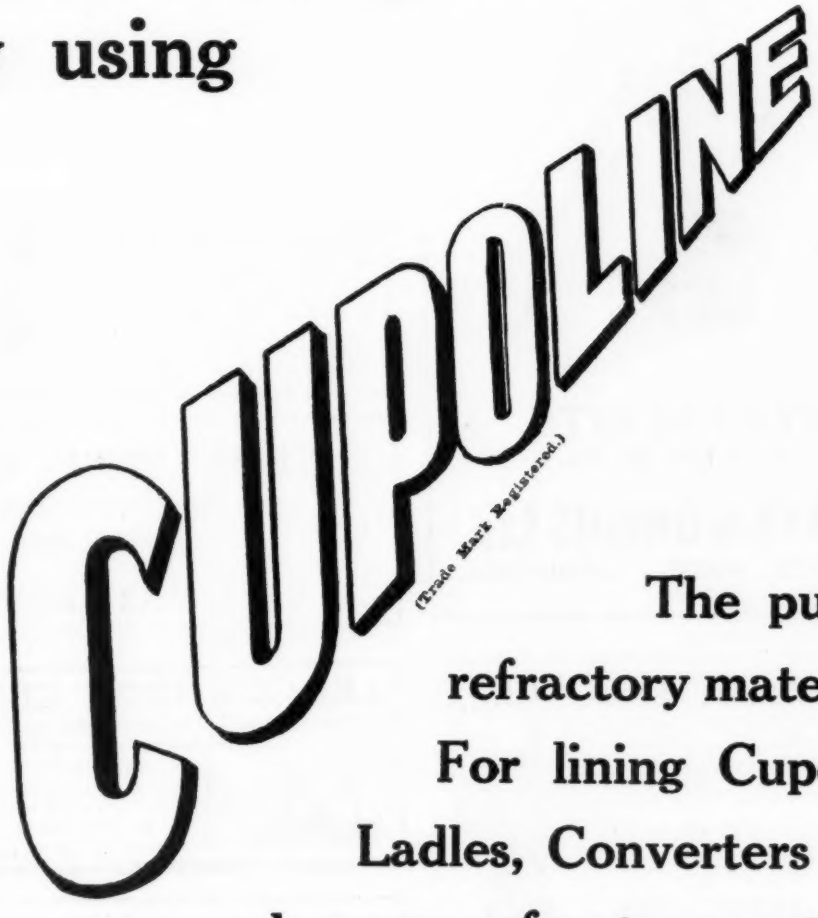

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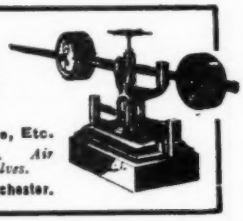

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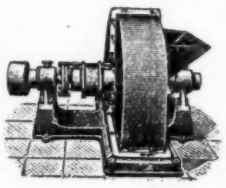

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No. 3 Soft	91.67	3.40	.20	2.90	.03	.70	1.10
No. 3 Medium	91.95	3.25	.35	2.60	.05	.70	1.10
No. 3 Hard	92.49	3.00	.45	2.30	.06	.70	1.00
No. 4 Soft	93.03	2.90	.50	1.80	.07	.70	1.00
No. 4 Hard	93.60	2.75	.65	1.40	.10	.70	.90
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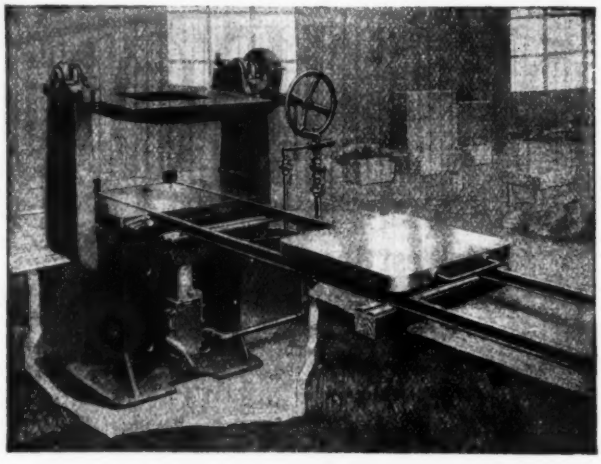

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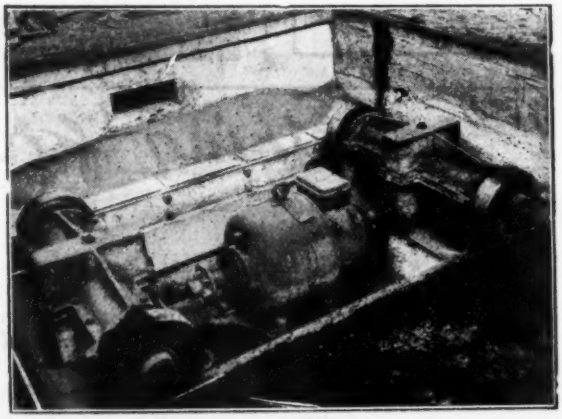

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